NOTES ON THE BOTANY, BREEDING AND ESTABLISHMENT OF OIL PALMS AND PRODUCTION OF PALM OIL

K. NEWTON.*

These notes were compiled following a tour in 1959 of oil palm centres in Ghana, Nigeria and the Belgian Congo.

INTRODUCTION.

ALTHOUGH the species of oil palm, *Elaeis guineensis* (Jacq.) is now grown for commercial production both in West and Central Africa, Indonesia and Malaya, the palm is indigenous to the humid forest region of Africa in an area roughly 15 degrees North to 10 degrees South of the equator. In this zone it occurs naturally in fresh-water swamp forest, often associated with Raphia with the greatest abundance in the West African coastal belt 100 to 150 miles in depth extending from Sierra Leone to the Cameroons. The palm cannot maintain itself independently under the heavy shade of closed forest canopy and the "wild" or native palmeries in West Africa are due to the influence of man by whom palms have been protected in various ways.

Two kinds of oil are obtained from the fruit:—

(*a*) *Palm Oil.*

This is extracted from the mesocarp or "husk" which contains 45 to 48 per cent. of a yellow-orange-red oil consisting mainly of the glycerides of palmitic and oleic acids. The oil is used mainly in soap manufacture but also in lubricating oils and if of high quality or refined, in the manufacture of edible fats. A high carotene content increases its importance in the local diet in West Africa. Extraction is carried out in the areas of production and the oil is exported in drums or bulk.

(*b*) *Palm Kernel Oil.*

This is extracted from the kernel or seed which contains approximately 56 per cent. oil consisting mainly of the glyceride of lauric acid. Its principal use is in the manufacture of margarine and other edible fats for which purpose the kernels are exported whole from the producing countries for extraction of the oil in the manufacturing countries. The residual cake is used as cattle food.

Until 1920 the world export of palm oil and palm kernels was from West Africa which still remains the main source of supply, the fruit being obtained from wild or semi-wild palms. Ghana and Nigeria together export approximately one-third of the total world export of 670,000 tons of palm oil and approximately one half of the world export of 930,000 tons of kernels. In Nigeria, which is the only West African country exporting large amounts of palm oil, plantations total less than 50,000 acres, whereas wild palms are estimated to cover four million acres. However, the fact that the oil palm in West Africa is primarily a food crop, with the result that local consumption is high (estimated at 100 lb. per head per annum in Nigeria) and also the fact that production is dependent mainly on wild palms, results in a weakness in the industry in Nigeria which is unlikely to improve in production or efficiency without the development of plantations.

In the Congo most of the palm oil still comes from wild palms but there has been considerable development of plantations. This has resulted in a steady rise in Congo exports and in view of the enormous plantings there, the Congo could be dominant in future world trade.

The development of the oil palm industry in the Far East dates back to the introduction of four plants to Java in 1848, two from Reunion and two from a conservatory in Amsterdam, all of the same racial stock. From there palms were introduced to Singapore Botanic Gardens in

* Agronomist, Lowlands Agricultural Experiment Station, New Britain.

1870 followed by a further movement in 1875 to Deli in Sumatra where Hallet in 1910 made the first large scale plantation with " Deli " seed. All palms in the Far East are said to have originated from this source and the first commercial planting was begun in Malaya in 1917. Hence, from about 1920, exports from Malaya began to enter the world market and the industry there was favoured by both its establishment as a plantation industry with very few small holdings and by the fact that there is virtually no local consumption of oil.

A certain amount of interest in the oil palm has been shown by some Central and South American countries and the United Fruit Company at one stage established 300 acres of oil palm in Costa Rica to replace the banana estates which had been hit by Panama Disease.

BOTANY.

The species belongs to the family Palmae, tribe Cocoineae. There are several other species of the genus *Elaeis* and one of these, *E. melanococca* (Gaertn.) a palm indigenous to tropical America, has been utilized for hybridization trials in the Congo because of its dwarf habits.

Morphology and Pollination.

The oil palm has a typically monocotyledonous root system, concentrated essentially in the surface three feet of soil but with a number of anchoring primary roots descending deep below the base of the palm. Roots are hydrophilus with a thick hypodermis, air spaces in the parenchyma and pneumathodes. Absorption occurs behind the root tip. Development of the trunk is not obvious until some three years after planting when the apical bud has attained full diameter. The palm carries 20 to 40 leaves at one time and as old leaves are shed, the leaf base remains attached to the palm for some considerable time. At the base of each leaf or frond of the palm an inflorescence develops, which is either male or female. The flowering begins when the palm is four to six years old and although either male or female inflorescences develop, they do so at different stages, so that fertilization is by cross-pollination, the pollen being mainly wind born. In all breeding work controlled cross-pollination is, of course, essential and to do this, the female inflorescence is usually covered by a large cloth bag well soaked in oil to render it pollen proof and with a small celluloid observation window through which the stage of development of the inflorescence can be observed and the pollen introduced. Flowering begins at the base of the female inflorescence, most flowers opening within 24 hours and remaining receptive for nearly two days. For cross-pollination work, pollen can be stored at five degrees C. and relative humidity 25 per cent. to 35 per cent. for some months without loss of viability. However, it is usual to check viability before use by germinating pollen grains for five hours on agar with fresh pollen grains as a control check. Agar used at W.A.I.F.O.R. is prepared from 0.5 gm. of maltose in 0.35 gm. of agar. This is heated, a drop placed on a slide, pollen blown on to the agar and the slide then stored for five hours in a moist atmosphere in a container or on wet filter paper in a petri dish before examination.

Sex Ratio.

As mentioned earlier, male and female phases alternate with one another on the one palm, the term sex ratio being applied to the ratio of female to male plus female inflorescences. Naturally, this ratio is of great importance in plantation production as it determines the potential number of fruit bunches developed on the palm. Fluctuations in annual bunch yields are largely due to variations in the sex ratio and, therefore, it becomes important to select palms with a naturally high sex ratio and also to devise cultural and manurial treatments which encourage it. It has now been shown that light is a most important operative factor in determination of sex ratio and that high hours of daily sunshine favour formation of female inflorescences. Male flowering originates in rainy seasons when light is a limiting factor. This effect is exemplified by the fact that in Malaya, where daily sunshine is high and rainfall well distributed, the female cycle is up to twice as long as the male cycle. Also, in Nigeria, female flowering is initiated in the dry season of two years previous when daily sunshine is in its highest period for the year. Sparnaaij (1959*a*) at W.A.I.F.O.R., considers that where light or sun are not optimum for the production of female inflorescences, as for example, in the Nigerian wet season, then nitrogen also becomes an important operative factor in determination of sex ratio. It has been established by British, Belgian and French research workers, that the inter-cropping of oil palms with food crops during the early years of establishment significantly increases yields for the following 15 to 20 years (Sparnaaij, 1959*a*). The reason for this increase is thought to be due to a reduction in the levels of soil nitrogen leading to an increase in the sex ratio. Further, the soil analyses for total nitrogen on several experimental plots at W.A.I.F.O.R. have shown a consistent and significant negative correlation between total nitrogen and sex ratio. These indications are supported also by the fact that nitrogenous fertilizers when applied to oil palms at the end of the wet season subsequently lead to a reduction in yields (Sparnaaij, 1960).

Classification.

Classification of varieties within the species has been principally based on either external or internal appearance of the fruit, as follows:—

A. Classification of external appearance based on colour of the exocarp—

1. *Nigrescens*:
   The unripe fruit is mostly deep violet or black with a colourless section at the base. On ripening, the fruit becomes either red in colour with a brown cap or orange in colour with a large black cap. These are two distinct sub-types, the red being the most common form.
2. *Virescens*:
   Fruit is green until just before ripening when colour slowly changes to red. The ripe fruit retains a small green tip. This variety is reasonably well known but rare in occurrence.
3. *Albescens*:
   Immature fruit is whitish in colour and ripens to a golden yellow or ivory. The type is exceedingly rare in nature and a simple recessive.
4. *Poissoni*:
   A variety which can occur as any of the above forms with the addition of a mantle of six sterile supplementary carpels containing oil as in the mesocarp. Occurrence is very rare.

B. Classification on internal appearance based on proportions of mesocarp, shell and kernel in the fruit.

1. *Dura*:
   Essentially a thick shelled form with a large kernel and thin mesocarp. The common type of wild palm in West Africa. Within the type a certain range of variation in both shell and mesocarp thickness occurs. The extreme form with very little mesocarp and very thick shell has been called "*macrocarya*" and occurs generally throughout Sierra Leone and in certain creek areas in Nigeria.
2. *Tenera*:
   A contrasting form to *dura* characterized by a thick mesocarp, which produces large amounts of oil, thin shell and small kernel. In some cases, separation of varieties into the *dura* or *tenera* class is difficult but the latter is always recognized by the presence of a ring of fine fibres in the mesocarp a little way from the shell.
3. *Pisifera*:
   This third form has no shell at all, only a very small pea-shaped kernel and is characterized by the common failure of the fruit to mature, the whole bunch going rotten despite normal fertilization and early fruit development (infertile *pisifera*). In some cases (fertile *pisifera*) fruit bunches do mature more or less normally but are very poor.

Early in World War II, the inheritance of the characters of the above three forms was demonstrated in the Congo and has since been confirmed to a large extent by studies in Nigeria (*West African Institute for Oil Palm Research*, 1954). Briefly, it has been shown that the *tenera* palm (AB) is a monofactorial hybrid between *dura* (AA) and *pisifera* (BB). Hence, self pollinated *tenera* palms give *dura*, *tenera* and *pisifera* progeny in the ratio 1:2:1.

Sparnaaij (1959*a*) considers that fertile and infertile *pisifera* forms may be mutant forms of *macrocarya* and *dura* respectively. This view is based on the fact that when a fertile *pisifera* is crossed with *dura* it invariably produces a very thick shelled *tenera* and when an infertile *pisifera* is crossed with *dura* the normal *tenera* is produced. Poels (1959) tentatively agrees with the above hypothesis but the point is not yet proven at either W.A.I.F.O.R. or Yangambi. However, Poels considers that just as *dura* types vary in shell thickness over a certain range so do *pisifera* types vary from those having slight shell (fertile) to those having no shell (infertile). Hence, in crosses between *pisifera* and *dura* a range of *tenera* types are produced as shown in Figure 1.

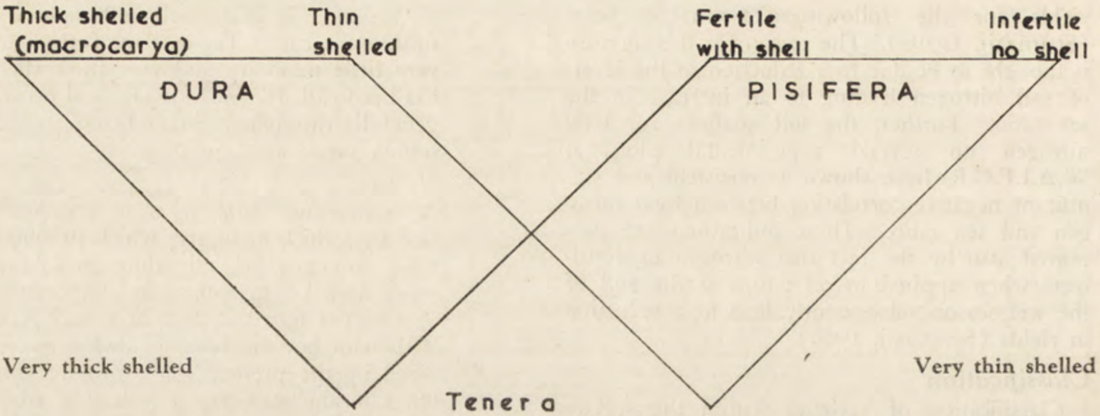

Fig. I.—Results of *Dura* x *Pisifera* crosses.

The two crosses shown give the extremes of the variation which may occur. At Yangambi, it is generally considered better to select *dura* with average shell thickness and cross these with infertile *pisifera* for production of good *tenera* types. The possibility that this may result in production of infertile *tenera* types has been suggested but Poels considers that the chances of this are less than one per cent.

Sparnaaij (1959*a*) has also suggested that there may be a connection between fertility in *pisifera* forms and sex ratio. He points out that the sex ratio in fertile *pisifera* forms is fairly normal whereas the sex ratio of infertile *pisifera* forms is abnormal in that production of female inflorescences is high. Therefore, it is probable that the palm cannot support nutritionally such a large number of fruit bunches with the result that they abort before maturity and rot.

4. *The Deli Palm*:

As pointed out earlier, the Deli palm is a form peculiar to the Far East, its origin being traced back to the introduction of four plants to Java in 1848. Essentially it is classed with the West African *dura* forms and behaves like *dura* when crossed but is differentiated from the latter by several distinct morphological and physiological characters as listed below. Sparnaaij (1959*a*) considers that the Deli palm can be distinguished visually from the African *dura* but Poels (1959) maintains that a fruit analysis is necessary to separate the two forms.

(1) In Malaya the fruit contains 60 per cent. mesocarp compared with 45 per cent. or less in West African *dura*.

(2) Mesocarp of the Deli fruit contains 45 per cent. palm oil compared with 48 per cent. in Nigerian *dura*.

(3) Leaves of the Deli are dark green and produced at a slower rate indicating a difference in photosynthetic activity.

(4) Vegetative tissue is softer and thus easier to harvest.

(5) Larger bunch size with few very heavy bunches rather than a large number of small ones.

(6) Bunches are less spiny and therefore easier to handle.

(7) The ripe fruit loosens more easily from the bunch.

(8) There is a tendency to low sex ratio and high abortion rate.

(9) Easier to germinate.

(10) More susceptible to crown disease (apparently physiological) and stem rot, but less susceptible to *Fusarium* wilt and deficiency chloroses.

(11) The Deli palm in Malaya produces bunches which contain approximately 61 per cent. fruit, whereas *dura* bunches contain approximately 66 per cent. fruit. However, because of the higher percentages of mesocarp, in the Deli fruit, the palm oil recovery from it is higher (28 per cent.) than from *dura* fruit (22 per cent.).

Although much higher yields of palm oil per acre are obtained from the Deli palm in the Far East than are obtained from the *dura* palm in Africa, the performance of the Deli palm in West Africa has been variable. In the Congo, however, the percentage recovery of oil from the Deli fruit, has remained superior to that from the *dura* fruit. (Poels, 1959).

5. *The Dumpy Palm.*

This is another *dura* type palm peculiar to the Far East which could be described as a "Dwarf Deli" and was discovered growing on a plantation near Kepong in Malaya in the 1930's as a low growing thick stemmed palm with the measurements shown in Table I (Jagoe, 1952).

Table I.

—	Girth at 4 ft.	Height at 15 years.	Height at 21 years 1941.
E 206	113 in.	11 ft.	13.7 ft.
Normal Deli	89 in.	17 ft.	22.5 ft.

When selfed, the Dumpy palm bred remarkably true to type with progeny showing a slow rate of height increase, vigour of growth, a high rate of inflorescence and fruit production and a high percentage of mesocarp (64.5 per cent.). However, percentage of clean fruit per bunch was low (54 per cent.). The dwarf character is desirable for easier and, therefore, cheaper harvesting and may extend the economic life of the palm. When crossed with tall Deli palms, the F_1's were found to be intermediate in growth and thickness and gave a high fruit figure per bunch of 67.8 per cent. It is now hoped to transfer this character to the Dumpy by backcrossing as well as producing *tenera* Dumpies by crossing with *pisifera*.

BREEDING.

The complexity of breeding programmes undertaken by oil palm research centres both in Africa and the Far East, is such that they cannot be dealt with other than briefly in these notes. An excellent outline of the work being undertaken at W.A.I.F.O.R. has recently been published (Sparnaaij, 1959*b*). It consists of three sections. In the main breeding programme, work is concentrated on the selfing and inter-crossing of selected *dura* and *tenera* palms, the progeny being planted out in *dura* x *dura, tenera* x *tenera* and *dura* x *tenera* progeny trials. Parent palms for the second generation of the breeding programme will be chosen from the most promising progenies, both crosses and selfings. In addition to the main breeding programme and linked to it, is the Deli breeding programme. Originally the aim here was to reproduce the most promising Deli palms only, but the programme has now become extended to include a number of Deli x *tenera* and Deli x *pisifera* crosses. This extension was decided upon as a result of evidence that combination of Deli and local material held more promise than pure adaption of the Deli palm to West African conditions.

In contrast to the primary emphasis in Nigeria on breeding within *dura* and *tenera* selections, research workers and planters in the Congo, the French Territories in Africa, Malaya and Indonesia are concentrating on the production of Deli *tenera* palms from a cross between the Deli palm and *pisifera* palms. The progeny from this cross has been shown to retain the high yield and vigour of the Deli palm but produces fruit with a much thinner shell and higher percentage mesocarp.

Should there be any interest in local planting of the oil palm in the next few years, the best approach would be the importation of high-grade seed from Malaya. The present recommendation of the Malayan Department of Agriculture is that commercial plantings should comprise half *dura* and half *tenera* palms, pending further proof of *tenera* types grown in pure stands. The required seed is available from Malaya, being the product of crosses between proved *dura* and *tenera* palms.

In order to meet possible future demands, the Department of Agriculture, Stock and Fisheries, has established seed gardens from imported seed comprising Deli, *dura, tenera* and *pisifera* palms and also the dwarf Deli (Dumpy palms). These gardens were grown from seed from proved high-yielding sources in Malaya and from about 1965 the Department will be able to produce sufficient seed of any type desired for planting about 1,000 acres a year. By that time, as a result of Malayan experience, it may be possible to recommend pure stands of *tenera* palms produced by crossing *dura* and *pisifera*.

A further breeding programme could be undertaken if there were sufficient justification for it in the Territory. Selected seed from all progeny lines in the breeding programme at W.A.I.F.O.R. is available if it can be established in a progeny trial. Alternatively, W.A.I.F.O.R. are prepared to supply mixed material from high-yielding lines and crosses for establishment of a mixed palm population with high-quality genetic constitution.

FIELD AND LABORATORY METHODS.

The laboratory procedure used at W.A.I.F.O.R. for fruit analysis is, briefly, as follows:—

1. The whole bunch is first sterilized in an autoclave.
2. Whilst still warm, fruit is picked out from the bunch and pounded carefully in a wooden mortar so that mesocarp is separated from the nuts but the nuts are not broken.
3. Pounded material from the mortar is then placed for extraction of oil into a "Carver Laboratory Press".
4. From the residue remaining after oil extraction, the ratio of fibre to nut is determined for the sample.
5. Oil is clarified in a Sharples Super Centrifuge.
6. An alternative procedure to the determination of mesocarp oil content by press extration is the utilization of data giving percentage moisture content of the mesocarp and relating this to oil content. The method relies fundamentally on the assumption that the mesocarp consists of oil, water and dry matter, and assumes a constant dry matter content of the pulp. Hence, the oil content of the mesocarp can be found at once when the moisture content is known. It is necessary, however, first to establish the correlation between mesocarp oil and water content for particular palm types such as *dura*. To do this, several direct determinations of oil content by Soxhlet extraction must be made and the negative correlation between oil and water content firmly established. When this has been done, oil content can be rapidly determined from moisture content. Both W.A.I.F.O.R. and I.N.E.A.C. workers have used the method successfully with a very low standard error (Chapas, Tinker and Ziboh, 1957).

ESTABLISHMENT.

Climate and Soils.

The crop requires relatively high temperatures and is cultivated only well within the tropics and usually below 1,000 feet above sea-level. Minimum rainfall requirements are set at 55 to 60 inches per annum but best yields are obtained with a rainfall of 80 to 120 inches per annum. An even distribution of rainfall is desirable and although this occurs in Indonesia and Malaya, these conditions do not obtain in West Africa where the crop is grown in areas with a pronounced dry season. In Nigeria, the dry season is associated with very limited rainfall and a fair amount of sunshine from November to March, whereas, the rainy season from May to October is characterized by limited hours of sunshine per day. These factors of hours of sunshine per day, annual rainfall and rainfall distribution, play an important part, in association with one another, in the determination of the number of female inflorescences and hence bunches of fruit which develop on the palm, as high hours of bright sunlight have a favourable influence on the production of female flowers.

With regard to soils, it is now known that the oil palm will grow on a wide range of soils provided there is no serious impediment to root development and that drainage is reasonably good. A high percentage of oil palms under cultivation are growing on poor soils and the full yield potential is commonly not achieved because of the low nutrient status. In Malaya and Indonesia high yields are obtained on moderately acid, heavy alluvial clays and on lateritic red earths. In Nigeria, much of the area on which oil palms are grown consists of acid sands which have loose brownish topsoil over a great depth of featureless non-mottled, non-gravelly, porous subsoil with coarse sand the predominant fraction and a clay content rarely exceeding 35 per cent.

A large area of soils on which oil palms occur in Ghana have been classified as Forest Ochrosols. These have developed from the intense weathering of granites and phyllites (Adu 1959). They consist mainly of a surface horizon of humus, sandy loam with pH 7.0

which overlies at three inches a brown loam or silty-light clay with pH 6.5. At eight inches this merges into a red-brown, light silty-clay to light clay in which there is at first abundant ironstone gravel decreasing with depth and a pH range of 6.0 to 5.5. The horizon continues to a depth of four to five feet.

Germination.

The oil palm seed is extremely slow to germinate and has a low rate of germination as a result of which germination has remained one of the persistent problems in the establishment of oil palms in West Africa. The presence in the seed of a rather tough testa together with a thin layer of thickened endosperm cells between embryo and the micropyle results both in a mechanical resistence to embryo development and retardation of the entry of air and water to the embryo in dry seeds. Hence it is generally found that germination is low, slow and erratic unless seeds are kept constantly moist and warm. Research work on the above problems has been carried out at several centres in Africa and the Far East although germination is apparently never such a problem in the latter area as in West Africa because of both climatic conditions and the fact that the Deli seed used in the Far East has better germination than *dura* seed.

Following on from attempts to improve germination by using whole fruits, cracked nuts, bored nuts, naked kernels and soaking seed in water and acid, various methods of germination have been evolved and elaborated. These techniques, which are all based on sowing the seed in a moderately moist, adequately aerated medium maintained at temperatures of 35 to 40 degrees C. have been well summarized by Gault (1953).

Malayan methods of germination are based on the use of open sand beds 30 inches in depth, the effectiveness of which can be increased by underlaying with compost and covering for a few hours in the middle of the day with glass frames to retain heat and moisture. Seed is not stored for longer than three months as beyond this period an appreciable decrease in viability occurs. Seed is sown three inches by three inches by one inch deep and watered twice daily giving a germination of 50 to 60 per cent. in nine months with seed of the Deli variety. Transplanting to the field nursery is carried out when the first leaf appears. Some Sumatran estates use steam germinators which may give up to 85 per cent. germination.

Methods used in both Ghana and Nigeria were found to be fairly similar, based on the use of special germinating chambers and following closely W.A.I.F.O.R. recommendations. Contrary to the experience in Malaya it has been found that seeds can be extracted from ripe fruit and stored for up to one year with little loss in viability before germination. Trials at W.A.I.F.O.R. have shown that 20 per cent. germination is obtained after holding for one month, 50 per cent. after five months and 58 per cent. after seven to nine months. Also seed stored for up to one year will sometimes give a burst of germination as soon as it is placed in the germinator. Consequently seed is usually collected throughout the year and in September placed in a germinating chamber. This enables most of the seed to be transplanted to a field nursery at the beginning of the rainy season in April. A thorough mixing of the seed with charcoal is necessary as exposed seed will not germinate well. Charcoal must be kept constantly moist but not wet or soggy and in many germinating chambers a can of water is placed near the seed trays both to assist in maintenance of humidity and to provide water at the correct temperature for watering seed boxes twice weekly. Each week, boxes are examined for germinated seed by either picking over the seed or separating the seed from the charcoal on a coarse mesh sieve. As soon as the radicle shows, seeds are removed and planted in a pre-nursery. Although germination of individual lots shows most unpredictable variations most seed germinates in the third, fourth or fifth months.

A diagram of a typical germinating chamber is shown in Diagram 1. Built, usually with concrete, it consists essentially of two chambers one above the other, separated by a concrete division. In the upper chamber, a wooden framework is housed to carry the wooden germinating boxes which can be run in through the door openings on either side of the chamber. The lower chamber remains empty and functions as a fire box for the unit.

Various optimum temperatures for germination have been advised by different research centres but for the typical germinator as described above the chambers should be maintained

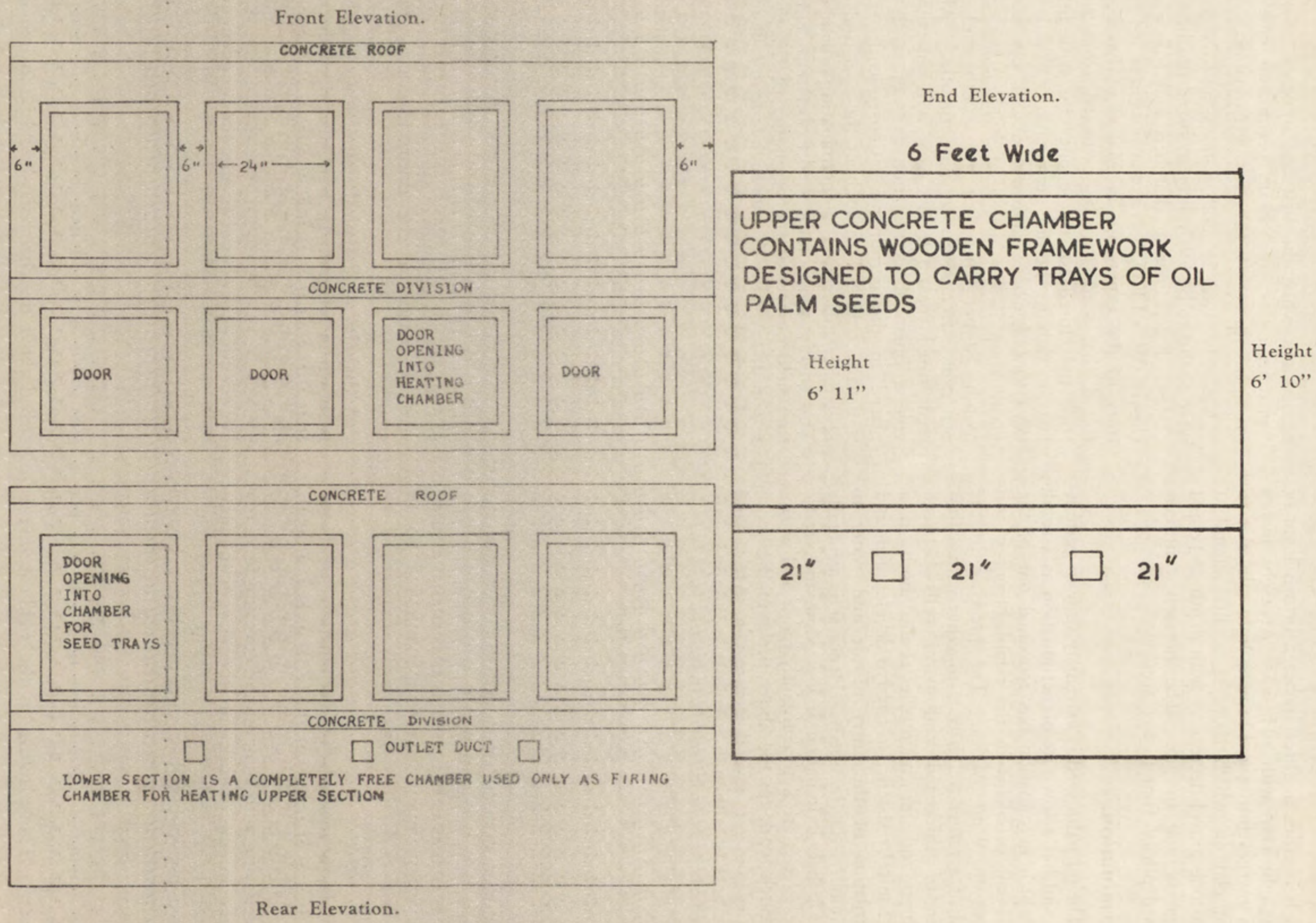

Diagram I.—Seed Germination Chamber used at Bunso, Ghana.

at 93 to 97 degrees F. One such unit inspected in Ghana operated at the temperature range of 90 to 104 degrees F. and suffered from lack of supervision.

Mulch germinators are in use in some areas. They are similar in construction to cocoa propagating bins and fitted usually with aluminium covers. Oil palm seed mixed with charcoal in the same manner as already outlined is packed into cubic wooden boxes which are placed in the concrete bin and packed around on all sides with finely chopped fresh green material. Grass is commonly used but a leguminous cover crop such as pueraria is considered superior. The mulch must be changed every two weeks with a light watering at time of renewal. A temperature variation of 86 to 94 degrees F. develops in this type of germinator.

Similar equipment to the above with some further modifications has been studied at I.N.E.A.C. Yangambi, a summary of the technique used being presented in a paper by Marynen and Bredas (1955).

Recent trends in research work at W.A.I.F.O.R. have been into the use of electrically controlled germinating chambers and the germination of seed in polythene bags in ovens. A large electric germinator has been built at the above Station and used for some time with considerable success (Rees, 1959*a*).

Development of the polythene bag technique began with the use of metal trays on to which seeds were placed without charcoal, covered with polythene sheet and watered with a fine spray. Temperature during germination has been found to be optimum at 110 degrees F. and moisture content of the seeds optimum at 17 to 19 per cent. for *dura* and 22 per cent. for *tenera*. The method facilitates watering, inspection, handling and accurate moisture control. Following on from this, it has been shown by Rees (1959*b*) that over 80 per cent. germination can be obtained by placing seeds in polythene bags and holding them at 39.5 degrees C. for ten weeks in an electric oven.

Pre-Nursery Beds ("Raised Trays").

Earlier mention has been made of the fact that in the Far East, oil palm seedlings are germinated in open sand beds and then transferred to field nurseries as soon as the first leaf appears above ground. In West Africa the nursery practice differs and seed, once germinated, is transferred to pre-nurseries or raised trays where they remain for a period of four to five months before transplanting to the field nursery. The raised trays vary in size, the variation depending to some extent on whether they are constructed of wood and to be movable or whether they are of fixed concrete construction. At Bunso Station in Ghana, wooden trays five feet by one foot by six inches and perforated at the base to allow drainage, are in use. These were filled with a 50/50 mixture of river sand and compost material all of which had first been sterilized by boiling in water. Sterilization of the planting medium in raised trays has been universally adopted in Africa to assist in the control of seedling diseases. In both Ghana and Nigeria the planting of germinated seed in raised trays is usually completed in December. They remain in here until the beginning of the wet season in April at which stage they are transferred to field nurseries, seedlings then having three to four leaves. A three inch by three inch spacing and one inch depth of planting is now commonly used as this gives more robust seedlings and also reduces losses from seedling diseases such as Anthracnose. The one and one-half inches by one and one-half inches spacing previously used has been discontinued. Trays require fairly frequent watering from at least twice weekly up to twice daily under severe Harmattan conditions and usually are given 50 per cent. shade. This is slowly reduced over a hardening period of six weeks prior to planting in the field nursery.

Pre-nursery beds are used in some areas as an alternative to raised trays. These are prepared by removing topsoil to a depth of four inches to six inches and refilling with a 12-inch layer of sterilized 50/50 mixture of sand and organic medium which raises the bed above ground level. Nursery beds are favoured where seedlings are to be transplanted to an immediately adjacent field nursery but where transportation to a field nursery is involved, the raised trays are more commonly used. At the I.N.E.A.C Station, Yangambi, in the Congo, pre-nursery beds were prepared rather more elaborately than in West Africa, soil being removed to a depth of 18 inches and replaced with rich organic topsoil collected from beneath established palm stands to form a raised bed. Seedlings in these beds were extremely vigorous with a good dark green colour. However, the Belgians apparently preferred to use baskets for pre-nursery seedlings rather than beds or raised trays and have done so with great success.

Two noticeably effective treatments used at the main W.A.I.F.O.R. Station in Nigeria were the application of a light mulch to seedlings at the two leaf stage and the spraying of seedlings with a solution of ammonium sulphate (half ounce/gallon each fortnight to each 45-inch by 21-inch tray).

Field Nurseries.

The Malayan technique of germinating seed in open sand beds has been outlined. Following germination, seedlings are transferred at the one leaf stage to field nurseries where they are spaced three feet by three feet and remain for 18 months.

The field nursery in West Africa comes into use after seedlings have been raised to the three to four leaf stage in pre-nurseries as described. Main objectives in the field nursery are:—

1. The production of strong, well-developed, disease-free seedlings which can be transplanted to the field with minimum loss.
2. Elimination of the cost of ring weeding pre-nursery seedlings in the field for a period of 12 months.
3. Protection of seedlings from field rodents and from drought, both factors being important in West Africa.

Notes on the establishment of oil palm nurseries and the effect of cultural treatments on losses in the nursery at the W.A.I.F.O.R. have been outlined by Anon. (1953*a*) and Allen (1954) respectively.

Shade is not used on field nursery beds in Malaya. Also, in Ghana and Nigeria where seedlings in nursery beds are mulched from one month after planting until they are lifted, no shade is used but great care is taken to see that seedlings receive at least one gallon of water per week. Unmulched nursery beds are usually shaded. At Bunso Station in Ghana pre-nursery seedlings are planted out in unshaded 12 feet to 14 feet wide field nursery beds at a spacing of two feet by two feet giving five rows of seedlings down the bed. Here they remain for 12 months until transplanted as balled-earth seedlings to the field.

Belgian Congo workers, on the other hand, use light shade over field nurseries for the first six to eight weeks after establishment.

Selection in the Nursery.

Workers at I.N.E.A.C., Yangambi (Poels, 1959), claim a close correlation between leaf size and number in the nursery and bunch and leaf production in the field. W.A.I.F.O.R. results have not confirmed this with the result that only the elimination of damaged or diseased seedlings is practised (Sparnaaij, 1955). No improvement in performance in the field has resulted from nursery selection. Nursery selection is considered essential in Malaya where up to 30 per cent. of the seedlings may be discarded.

Transplanting to the Field.

Ball-of-earth planting is recognized both in Africa and the Far East as being the only safe method of transplanting oil palm seedlings. Details of the technique have been outlined by Toovey (1953). Before planting in the field older leaves are usually trimmed, particularly under dry conditions. However, although this method may reduce field losses to as low as one per cent. as against up to 50 per cent. loss when the alternative "naked root" system is used, this latter method is generally practised in West Africa where oil palm seedlings are to be distributed to peasant farmers. Most peasant farmers have to transport their seedlings over considerable distances from the distributing centres to the planting areas with the result that it is completely impracticable for them to receive seedlings in the balled-earth form. To overcome this difficulty, workers at W.A.I.F.O.R. have developed a technique for distribution of naked root seedlings which, although still inferior, solves the problem to a certain extent (Anon., 1959).

In the Congo palms are removed as ball-of-earth seedlings with the aid of an iron collar which is fitted over the seedling and pressed down into the nursery bed to cut the roots.

Under peasant farming conditions in West Africa, preparation of land (clearing, lining, holing) for seedlings is haphazard, the bulk of the farmers' palms being grown in association with foodcrops, cacao and in some areas Kola nut (*Cola nitida,* A. Chev.) and natural vegetation.

Areas cleared under supervision in Ghana are clear felled and burnt prior to planting if the oil palm stand is to be intercropped with foodcrops. Where no inter-cropping is intended burning is usually not practised. Balled earth seedlings are planted in holes three feet by three feet by three feet filled with topsoil. Data on the cost of establishing an oil palm plantation have been prepared (Anon., 1953*b*). These show that in Nigeria 96 man days per acre are absorbed in establishment in heavy forest to which can be added a further 12 man days per acre for germination, pre-nursery and nursery work. Figures quoted from the Belgian Congo on cost of establishment (excluding all nursery work) are:—

Heavy forest—95 man days per acre.

Medium forest—83 man days per acre.

Light forest—70 man days per acre.

Replanting.

The necessity for replanting on oil palm estates may arise as a result of one or more of the following factors.

(*a*) Low yield as a result of senility. This usually becomes an important factor after 30 to 40 years.

(*b*) Increased harvesting costs as a result of palm height. Height increases lead to difficulty in reaching the bunches with harvesting tools and also a tendency for bunches to burst when dropped to the ground thus increasing costs of gathering.

(*c*) Replacement of low yielding palms with higher yielding types such as *tenera.*

Investigations into the problem of replanting old palm stands have begun in both Nigeria and the Belgian Congo and are described in detail in the literature. (Gunn, 1958*a*; Gunn, 1960 and Marynen and Gillot, 1957.)

The following points have emerged from results:—

1. The system of "live felling" old palms which is used in Malaya has shown sufficient promise to warrant further investigation.
2. In Malaya it is common practice to fell 50 per cent. of the palms initially and the remainder in a later period, but it is recognized that interplanting alternate rows of old palms with seedlings causes a reduction in yield from the seedling palms if the older palms are allowed to remain too long in the stand.

   A reasonable percentage kill of old palms can be obtained by introducing six ounces sodium arsenite per palm into a hole bored with a brace and bit. It is suggested that a quicker kill may be obtained with less sodium arsenite in larger holes, although I.N.E.A.C. workers gained a ninety-seven per cent. kill at the higher concentration (Marynen and Gillot, 1957). Application during the wet season has proved more satisfactory than in the dry season or during early rains.
3. The most satisfactory method of replanting old palm stands which has emerged from an experiment at the W.A.I.F.O.R. main station is to fell alternate East to West rows of old palms one year after planting young palms and then fell the remaining rows of old palms after a further three years cropping (Gunn, 1960). Young palms have come into bearing at this stage. Poels (1959) also recommends the above as the best method for replanting but suggests poisoning of palms rather than felling.

Harvesting.

Plantation palms begin bearing in the third, fourth or fifth year but some wild palms in West Africa rarely start to bear before they are 20 years old. The rate of leaf production, which is paralleled fairly closely by production of inflorescences increases rapidly until six to seven years, remains constant for some years and eventually slowly decreases. The number and weight of bunches increases fairly rapidly to 10 to 15 years, and remains constant until the 20th year and then falls away slowly. Very little fruit is produced after 60 years and generally replanting is carried out after 30 to 40 years. The optimum time for harvesting bunches is when the majority of fruit in the bunch is just ripe. This will occur five to six months after pollination and is indicated by both a change in colour of the fruit from purplish black to orange red and the loosening of the fruit in the crown of the bunch. On some estates bunches are harvested when four to five fruits have fallen from the bunch to the ground. Harvesting at the correct stage of ripeness is most important as early harvesting results in both loss of fruit fallen to the ground and an increase in the free fatty acid content of the fruit due to the action of an enzyme in the mesocarp which splits the oil into free fatty acids and gylcerol.

Normal estate practice is to harvest every seven to 10 days. This frequency together with good factory extraction techniques gives an oil with 2.0-2.1 per cent. F.F.A. In some cases the harvesting frequency is extended to 10 to 14 days with a resultant increase in F.F.A. content to 2.7-2.9 per cent.

As may be expected, harvesting techniques vary from place to place and between peasant farmers and estate labourers. Generally, however, harvesting on estates is done with sickles on long bamboo poles with which one subtending leaf and the fruit bunch are cut off. In some cases estate labourers and in nearly all cases peasant farmers climb the palm to harvest the fruit bunch using a rope support to do so. On reaching the crown of the palm the frond subtending the fruit bunch and then the bunch are cut with a variety of shaped bladed tools.

Pruning.

General estate practice is to remove only the frond subtending the fruit bunch during harvesting operations and to remove any dead or dying leaves twice yearly. W.A.I.F.O.R. experiments have shown this routine to be beneficial but any more intense pruning of palms has a deleterious effect (Gunn, 1958*b*).

PRODUCTION.

Processing by African Farmers.

Two methods are used:—

Hard Oil Process.

After harvesting, bunches are heaped, covered with bags and allowed to ferment for seven to 10 days until fruit can be easily shaken from the bunch. Fruit is then transferred to wooden or stone pits where it is pounded during the first day of the extraction process. Addition of boiling water together with further pounding on the second day results in extraction of the bulk of the oil which, together with water, is run off down a slope from the container or mortar for collection. Finally, the pounded fruit is covered with cold water and thoroughly macerated by treading, the oil rising to the surface of the cold water where it is collected The method can yield up to 15 or 16 per cent. oil on weight of fruit but free fatty acid content is always high.

Soft Oil Process.

Under this method of extraction fruit is softened and loosened from the bunch by boiling with water in pots or drums, the heat leading to enzyme death and hence a check to the development of free fatty acids. Softened fruit is pounded immediately upon removal from the boiler, nuts are extracted by hand and the residual fibre squeezed to obtain the oil. Recovery of oil by this process is about 12 per cent. on the weight of fruit but the free fatty acid content is much lower in comparison with the first method.

Both processes are improved in certain instances by the use of hand operated oil presses giving a higher percentage recovery of oil. If these are used in conjunction with recommended procedures for preparation of fruit before pressing, oil with less than five per cent. free fatty acid is produced. Oil quality depends primarily on ripeness of the fruit at harvesting and on boiling the fruit soon after harvesting.

At the Bunso Research Station in Ghana a refined soft oil process is employed for extraction of oil from experimental plot bunches as follows:—

1. Bunches are first chopped into small sections and left heaped for one to two days depending on the ripeness of the fruit.
2. Fruit is separated from bunch sections by beating with a foot fork.
3. After sieving on quarter to half-inch mesh to remove small foreign matter the whole fruit is boiled for a minimum boiling time of 50 minutes. In practice, boiling continues throughout the morning, the fruit being removed in batches for pounding in a large mortar to loosen the mesocarp from the nut. In this way a continual supply of hot fruit is available for pounding which is consequently made easier and more efficient. Boiling time is not greatly important, although as it is extended so the uptake of water by the mesocarp increases and the water content of oil subsequently extracted increases. In turn this necessitates an extension of the final purification stage.

4. From the mortar, pounded and macerated material is transferred to a press for oil extraction. At Bunso a "Deutcher" press is used, the type being manufactured with either a one cubic foot or two cubic feet capacity. The smaller model will handle approximately 600 lb. of fruit in three hours with two pressings. Residual material (fibre and nuts) from the first pressing is spread on trays to allow hand picking of

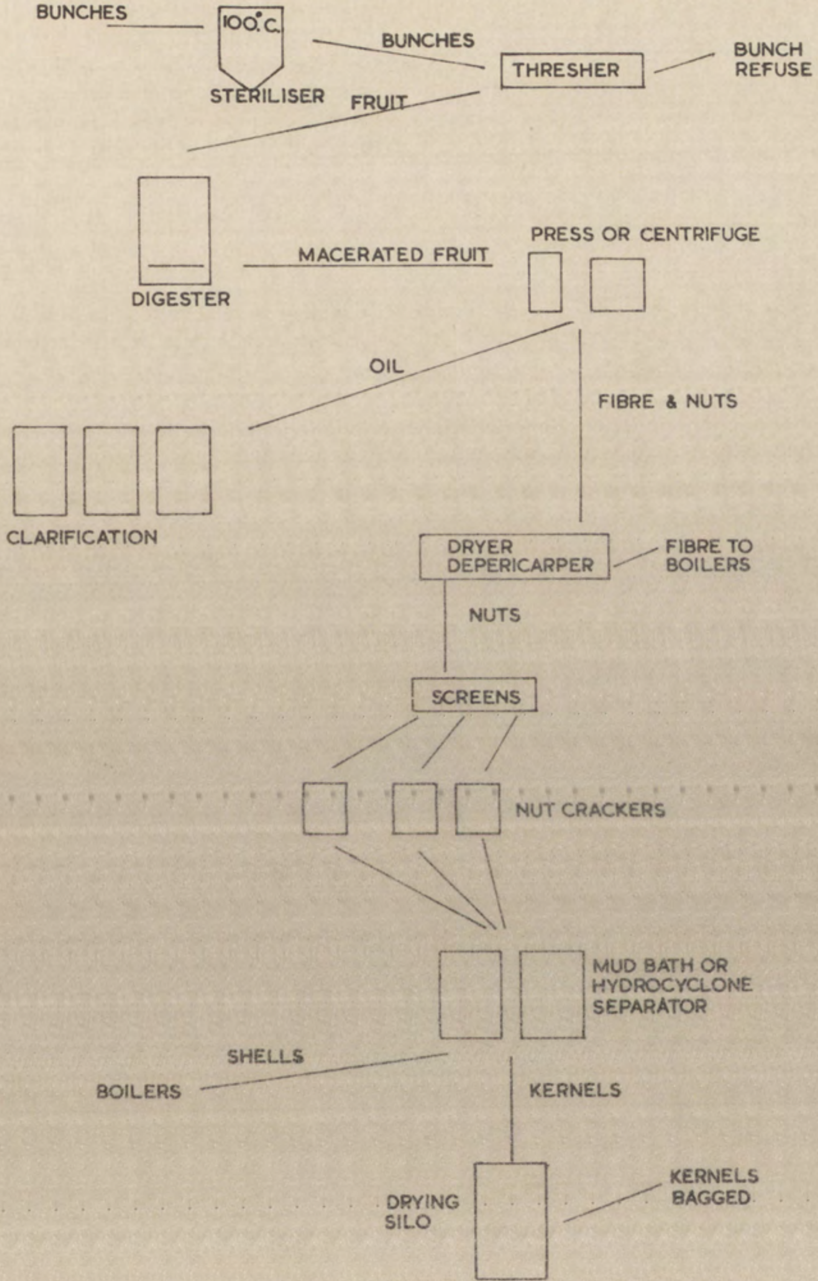

Diagram 2.—Diagrammatic Representation of Factory Processing.

nuts and the remaining fibre is then " fried " in a drum over a fire for two to five minutes before returning to the press for a second pressing. Recovery of oil after two pressings is 10 to 12 per cent. of fruit weight.

5. Purification of the red extracted oil is achieved by boiling for five to 10 minutes to remove excess water and sieving through a fine mesh to remove foreign matter.

6. Nuts are sun dried for two or three weeks prior to cracking in a mechanical cracker for kernel extraction and the mud bath separator is used for separation of kernels and shell by flotation. Density of the bath has usually to be adjusted before best separation can be obtained but the figure generally lies between 1.1 and 1.2. Sea water can be used as a substitute.

7. Four to seven days sun drying of the kernels is normally adequate before grading and bagging for export.

Factory Processing.

Factory processing of the oil palm fruit on the plantation is aimed at both the extraction and clarification of oil from the pericarp for export and the production and preparation of kernels from which oil is extracted in larger factories situated for example in the United Kingdom.

A diagrammatic representation of the essential stages of processing is shown in Diagram 2.

In West Africa much of the processing is carried out in Pioneer Oil Mills—small oil extraction factories which have become established in recent years and are capable of extracting 20 to 21 per cent. oil on weight of fruit and giving oil of good quality. As will

Plate I.—' Stork ' Factory.

be shown these units have certain defects and are not popular with producers who consider prices paid too low. Sale and installation of Pioneer Mills is controlled by the United Africa Company who can provide factories of two sizes, the "Minor" and the "Major". These factories have not been designed and manufactured by any individual engineering company but consist of a combination of equipment purchased from various sources. The efficiency of processing suffers accordingly. In 1959, the smaller type of Pioneer "Minor" could be purchased for £18,000 sterling. It requires a minimum supply of 1,900 tons of bunches per annum. For optimum efficiency and economy of production, some 3,800 tons of bunches per annum must be handled. One of these units installed at W.A.I.F.O.R. has been run for some time at a total cost of £900 to £1,000 sterling per month including depreciation at 10 per cent. and costing of bunches supplied to the factory at £6 per ton and labour at 4s. per day. Gross return from the factory including kernels has varied between £1,300 to £1,500 sterling per month.

Larger estates, particularly in the Congo, have installed different sized models of a very efficient and compactly designed type of factory almost wholly manufactured in Holland by Gebr. Stork & Co.

Unfortunately, none of these "Stork" factories are in the same price range as the Pioneer "Minor", the smallest type costing £52,000 sterling (See Plate I) and requiring a minimum supply of 10,000 tons of bunches per annum. A unit of this size in operation at the W.A.I.F.O.R. is being run at a total cost of £1,300 per month including depreciation at 10 per cent. and costing of bunches at £6 per ton and labour at 4s. per day. This factory produces 45 to 50 tons of oil per month which, together with kernels, gives a gross return of £1,800 per month.

At the Lalome Estate in the Congo a much larger "Stork" factory costing £500,000 sterling was inspected. Production from this unit at the time was 700 tons of oil per month plus 125 tons of kernels but its maximum capacity was rated at 1,900 tons of oil per month plus 340 tons of kernels.

Details of Processing in a Small "Stork" Factory.

Sterilization.

Bunches delivered from the field to the factory are, firstly, steam sterilized for a period of one hour with the object of (*a*) arresting enzyme action in the fruit and killing micro-organisms (*b*) loosening the fruit in the bunch

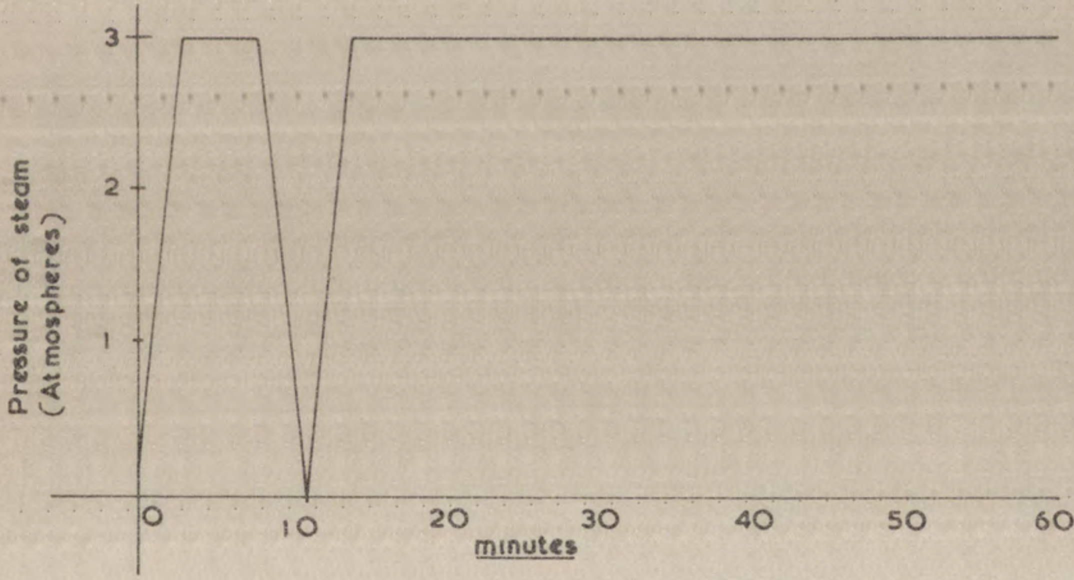

Fig. 2.—Standard Method of Air Expulsion used by W.A.I.F.O.R.

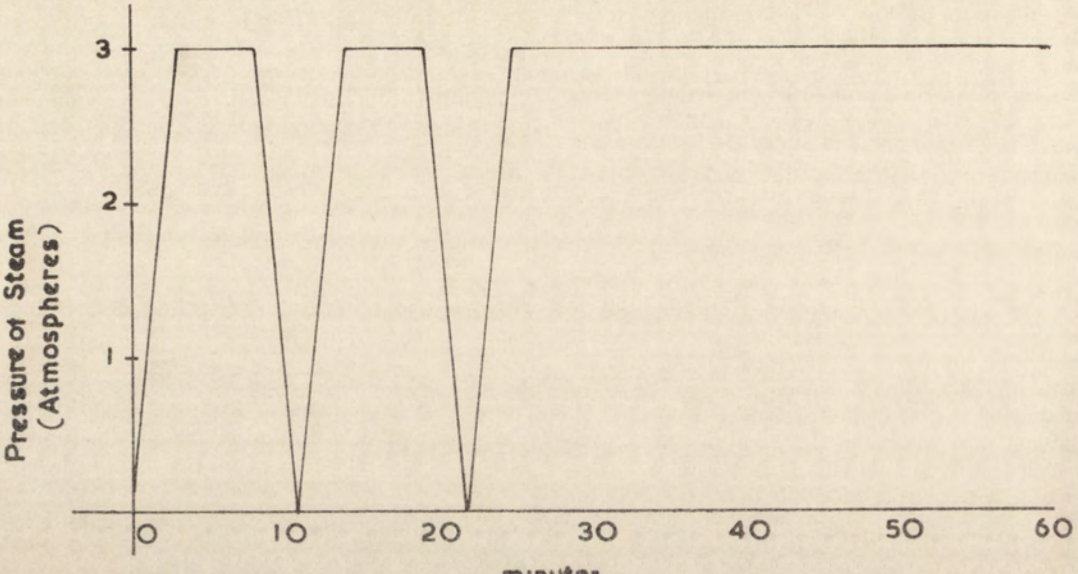

Fig. 3.—Method of Air Expulsion used by Palmol.

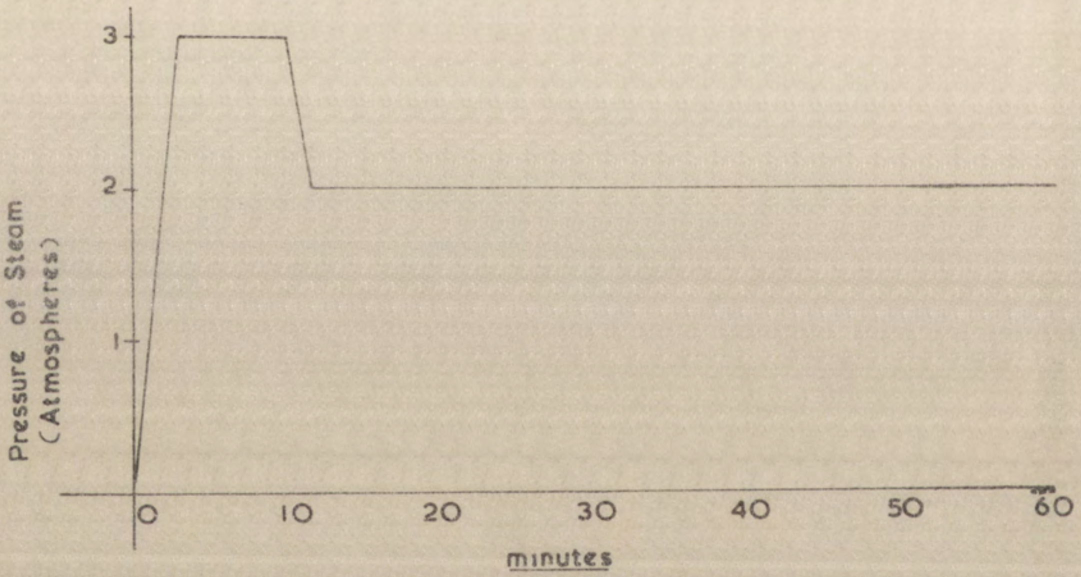

Fig. 4.—French Method of Air Expulsion.

to facilitate threshing and (*c*) coagulation of proteinaceous material. Smaller type sterilizers are usually heated by two or three jets of steam under pressure for a period which may vary from 40 to 90 minutes but which is usually initially set at 60 minutes and later adjusted as experience shows necessary. Within the sterilizer, a temperature-time application which is too low, results in hard bunches of fruit thus increasing the difficulty of threshing and if too high causes colour to run from the nuts into the pericarp imparting a dark brown colour to the oil extracted at a later stage. The aim in sterilization is to raise the temperature at the centre of the sterilizer to 100 degrees C. and hold it there but this is complicated by the necessity to remove air entrapped by the bunches.

Air must be expelled, as its presence during sterilization can lead to oxidation of the oil. Three techniques are commonly employed to eliminate air from the sterilizer.

Plate II.—Fruit bunches being loaded into top of sterilizer.

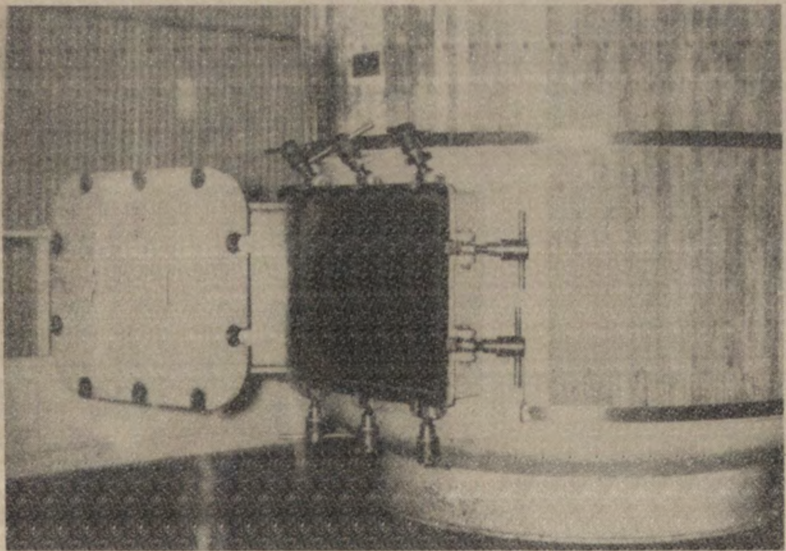

Plate III.—Bunch sterilizer of vertical construction.

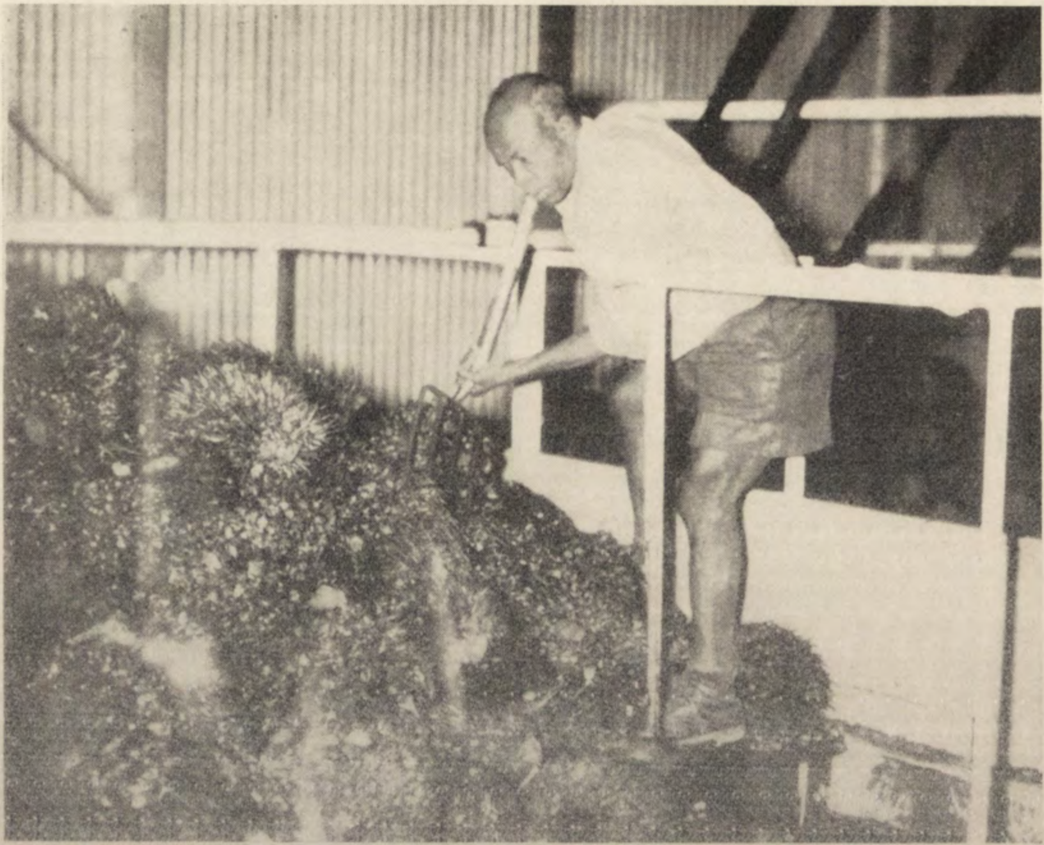

Plate IV.—Fruit bunches from sterilizer being fed into a stripper.

(*a*) Steam pressure is raised to three atmospheres, held for five minutes and then released through a valve. This results in emission of air together with steam. Pressure is again raised to three atmospheres and held for the remainder of the sixty minutes at this level.

(*b*) Steam pressure is raised to three atmospheres and held for five minutes before releasing as in method (*a*) but the procedure is repeated a second time before pressure is built up and held at three atmospheres for the remainder of the 60-minute period.

(*c*) Steam pressure is raised to three atmospheres and held there for five to 10 minutes before lowering to a pressure of two atmospheres which is maintained for the remainder of the 60-minute period.

There are two basic designs for sterilizers used in African factories:—

(*a*) *Vertical Sterilizer* (see Plates II and III).

This type is commonly used in Pioneer Mills and also in the smaller " Stork " factories and consists essentially of a reinforced vertical cylindrical chamber with a loading door at the top and an unloading door at the bottom. It has the disadvantage that during the sterilization process a certain degree of bumping and settling of the fruit can occur as pressure is released, which not only increases the difficulty of extracting the bunches from the bottom door on the sterilizer, but also causes fruit to separate from the bunch, thus increasing handling costs. A further disadvantage is that the bumping and compression leads to the premature extraction of some pericarp oil by pressure. However, the units are fairly satisfactory for the smaller type factory as they are designed in various sizes to handle up to five tons of bunches per hour and can be added to the factory production line as fruit intake increases.

(*b*) *Horizontal Sterilizer.*

The type of sterilizer used in large factories again consists essentially of a cylindrical chamber but in this case the chamber lies horizontally at ground level with one end consisting entirely of a door through which the bunches, carried in small steel rail-cars, are introduced. The bunches are thus held in the chamber without contact with the walls and bumping and settling are not the problem that they are in the vertical type sterilizer.

Threshing or Stripping.

From the sterilizer, bunches are conveyed directly to the thresher (see Plates IV, V and VI) where fruit is separated from the bunch either by a process of tumbling in a rotary drum tumbler or stripping by mechanical beating. Bunch refuse from this stage can be used as a potash fertilizer after burning, for preparation of compost or as a mulch for nursery seedlings.

Digestion.

The function of the digester, which is an upright steel cylinder unit with a false bottom for collection of oil and water (see Plate VII), is to

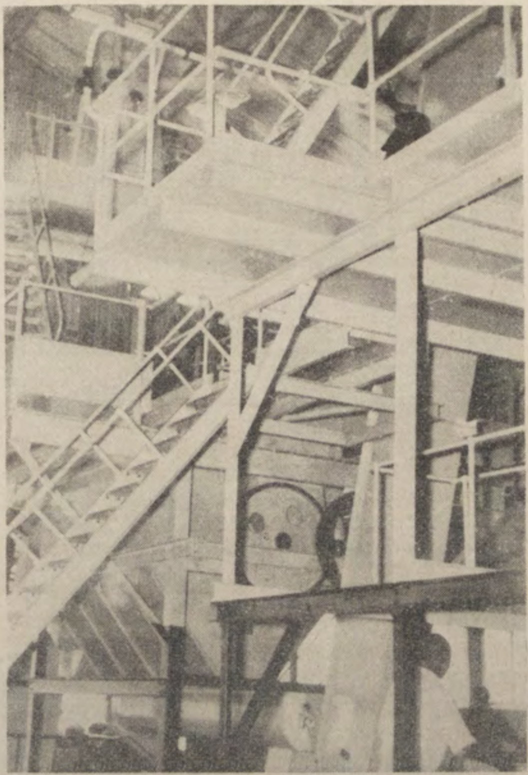

Plate V.—The thresher located below and to one side of the bunch steriliser with loading platform above.

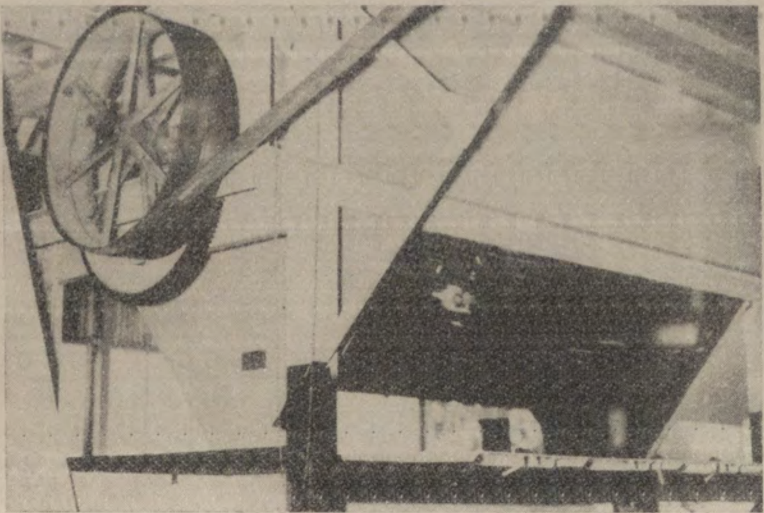

Plate VI.—Close-up of tumbler type thresher.

macerate the fruit, loosening the mesocarp from the kernel and to break up the oil cells by heat. It is essential that the unit be steam jacketed, steam injected and have provision for the addition of hot water for successful operation.

Macerated material from the digester is fed into either a press (see Plate VIII) or centrifuge for extraction of oil. The choice of the method of extraction to be used should be considered in the light of the following factors:—

(*a*) A greater quantity of oil can be extracted by use of a press but this oil is dirtier than oil extracted by centrifuging and generally speaking the amount of clarified oil obtained from either process is approximately the same.

(*b*) Oil extracted by pressing usually contains non-oily solids (fibre and sand), a fraction which is four to five per cent. greater than in oil extracted by centrifuge. An average figure for non-oily solid content of press oil is seven per cent. compared with the average figure for centrifuge oil of three per cent. However, this disparity is offset by the fact that residue after press extraction contains only eight to 12 per cent. of oil to dry fibre, whereas, residue after centrifuge extraction contains 12 to 15 per cent. of oil to dry fibre. Hence, although press oil contains a higher percentage of non-oily solids, a higher percentage of oil is extracted and the end result is that both methods produce about the same amount of oil.

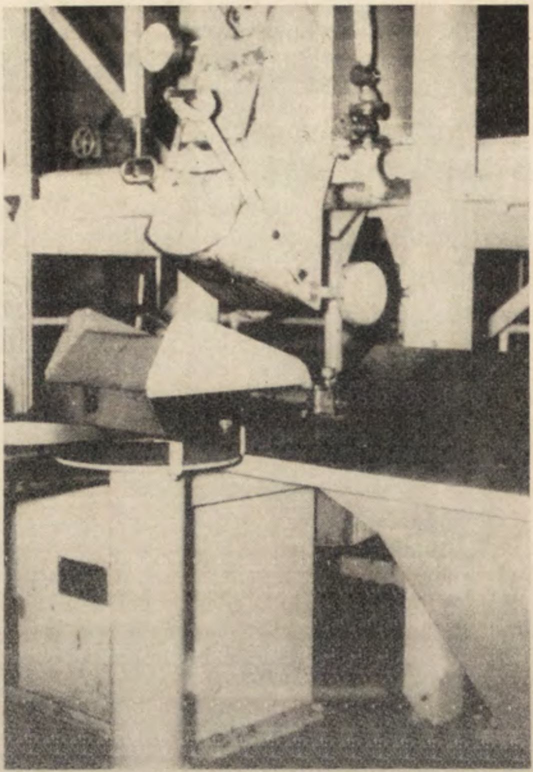

***Plate* VIII.—Hydraulic press used for oil extraction.**

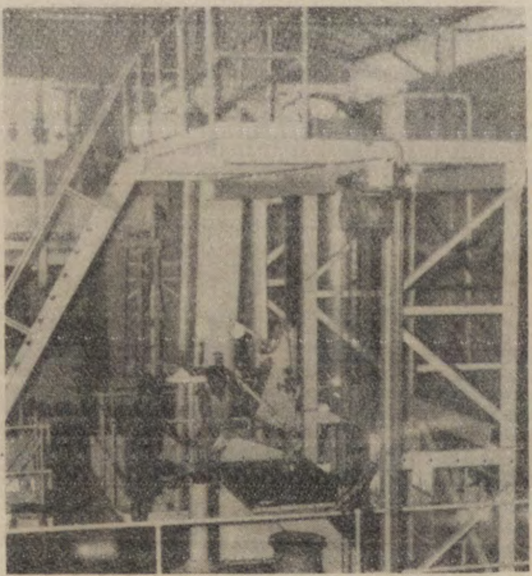

***Plate* VII.—Tall cylindrical fruit digester.**

(*c*) Because of variation in fruit characteristics, certain types are more suited to pressing whereas other types are more suited to centrifuging. In relation to oil extraction, fruit may be classified into three main types:—

1. Fruit with a thick shell and thin pericarp;
2. Fruit with a thick shell and thick pericarp; and
3. Fruit with a thin shell and thick pericarp.

Fruit of the first class is best processed by centrifuging, as pressing tends to result in a high percentage of broken shell because of the lack of any cushioning action by the thin pericarp. If a press is used for this type of fruit the problem can be overcome to a certain extent by mixing additional fibre with the material to give a greater cushioning effect. The second class of fruit is suited to either technique of extraction. With the third class of fruit there is the danger that the volume of nuts will be too small in relation to the volume of pericarp for press extraction as the nuts will not provide a sufficient number of pressure points. Centrifuge extraction is, therefore, recommended for this type but if press extraction is used more pressure points can be obtained in the material by addition of nuts to the material.

On plantations of mixed palm types the selection of either method is not usually a problem as difficulties only arise in processing fruit from pure stands of one palm type.

Clarification.

A system involving the use of settling tanks (see Plate IX) is used for clarification of extracted oil. Crude oil, collected from the presses or centrifuge, is pumped or blown to the first settling tank from which the upper 50 per cent. is later drawn off into a second tank. The residual sludge and oil in the first tank is then boiled by means of steam injection and after a further settling period the remaining oil is drawn off into the second settling tank. Here the oil is heated by means of a closed steam coil to 105 to 110 degrees C. which enables the water content to be reduced below one per cent. From this stage oil is finally passed through filter presses or centrifugal clarifiers for removal of the last traces of dirt before pumping into drums for shipment.

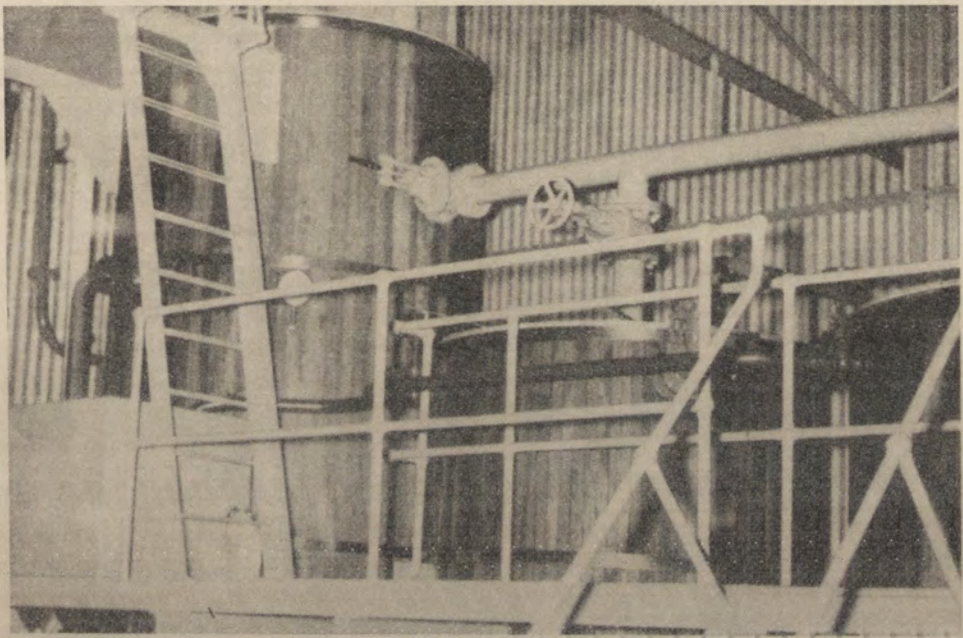

Plate IX.—Settling tanks used for clarification of oil.

Preparation of the Kernels.

Residual fibre and nuts from the press or centrifuge are conveyed to a dryer-depericarper (see Plate X) where nuts are separated from the dry fibre which is utilized for firing the factory boilers. Dried nuts are then processed in a nut cracker and kernels and shells separated in either a mud bath separater or a hydro-

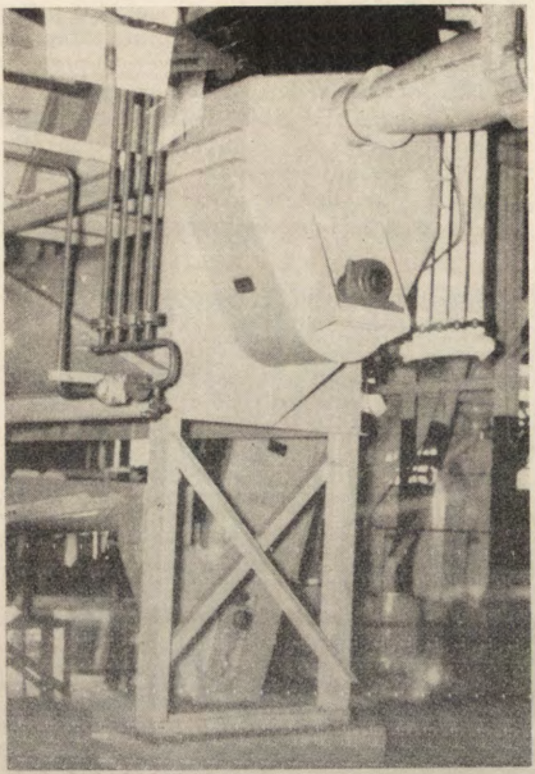

Plate X.—The Dryer-Depericarper.

cyclone separator (see Plate XI). As with the fibre, shells are used for firing the boilers (see Plate XII) while the kernels after thorough drying in a silo are bagged for shipment overseas.

Details of Processing in a Minor Model "Pioneer" Mill.

Sterilization.

A fruit sterilizer is used as compared with the bunch sterilizer used in "Stork" factories. For this process bunches must first be quartered and heaped for two days after which fruit can be separated by beating with a fork. The fruit sterilizer has a capacity of only four cwt. and the duration of the sterilization process is only 15 minutes at 20 to 30 lb. pressure of steam.

Digestion.

From the sterilizer, fruit is man-handled to a rather poorly designed digester in which it is macerated only. Absence of a steam jacket causes a failure of the oil cells to break down under the action of heat as in the "Stork" digester.

Centrifuging.

Macerated material from the digester is again man-handled to a centrifuge where it is processed for 11 to 14 minutes. The Pioneer centrifuge is not covered at the top as a result of

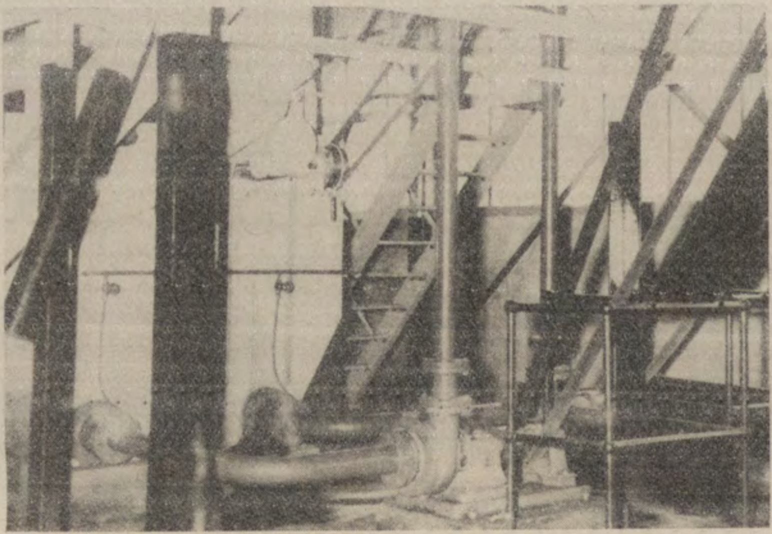

Plate XI.—The separator for removal of shells from kernals.

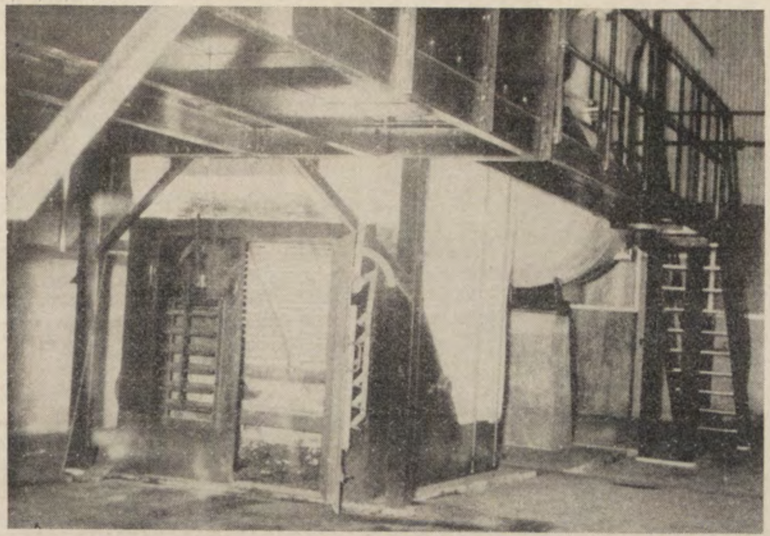

Plate **XII.—Boiler units.**

which air is dragged into the unit during centrifuging causing a drop in temperature from 70 degrees C. to 35 degrees C. Percentage recovery of oil is poor, the residual material containing 15 per cent. oil on a dry fibre basis compared with a figure of 12 per cent. for a more efficient type of centrifuge.

Clarification.

The process is similar to that used in a "Stork" factory.

Preparation of the Kernels.

Nuts and fibre from the centrifuge are transferred to a "fibre-separator", a rather inefficient machine of poor design based on the principle of a cotton gin. Following separation and drying, cracking takes place, the type of nut cracker used being similar in design to those used in a "Stork" mill. These units consist essentially of a hollow shaft rotating at high speed within a steel cylinder. Nuts, fed into the top of the hollow spinning shaft fall as far as an opening in the lower end of the shaft through which they are ejected at high speed striking the wall of the containing cylinder and breaking. In the "Stork" factory nuts are first graded into two or three sizes and then fed into nut crackers in which the speed of rotation of the shaft is varied according to the size of the nuts with the result that all nuts are broken. In the Pioneer Mill only one nut cracker is used with the result that the larger nuts are not broken as shaft speed is too slow and the smaller nuts are smashed because shaft speed is too fast. A further problem in this process which is common to all factories arises with *tenera* type nuts. These have a coating of fibre on the shell as well as a dense fibre mantle. *Tenera* nuts ejected from the rotating shaft nearly always strike the wall with the fibre mantle foremost and in many cases the shell fails to break. "Palmol" are trying to overcome this problem by doubling the distance between the wall of the cracker and the centre shaft so that the fibre mantle is forced around by air resistance allowing the rounded end of the nut to strike the wall.

One further problem in the Pioneer Mill in connection with nut cracking is to obtain sufficient heat to dry the nuts prior to cracking. Unless nuts are thoroughly dry before cracking the shell and kernel will not separate satisfactorily. In larger factories the problem is easily overcome as there are adequate heating facilities. However, in the Pioneer Mill nuts must be heaped for one or two months and a slight fermentation heat developed before satisfactory processing is obtained. Even so, separation is not good, some kernels adhering to the shell after cracking.

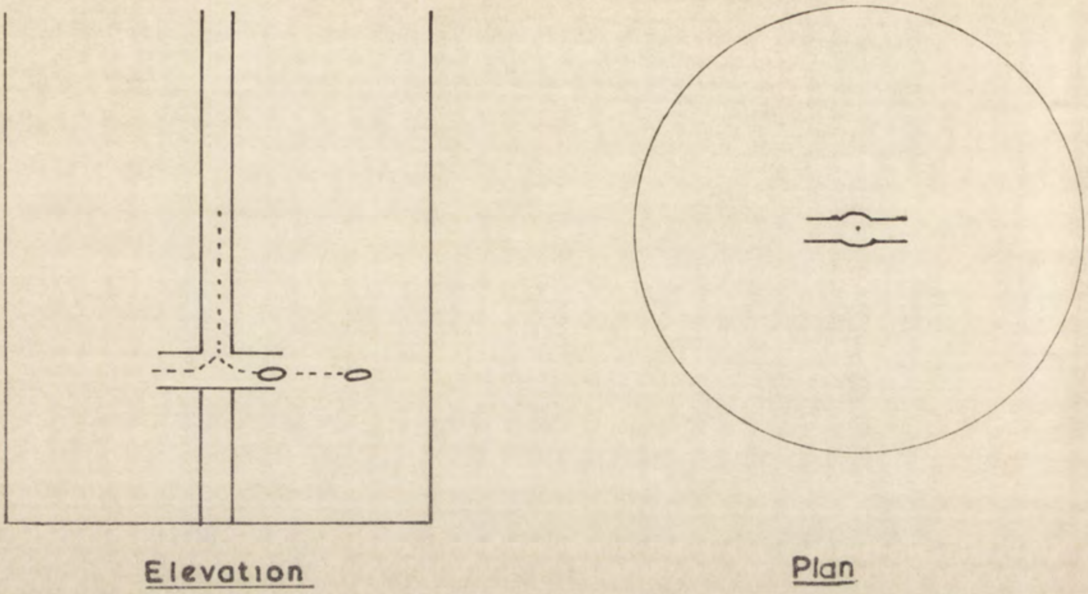

Fig. 5.—**Palm kernel nut cracker.**

Mud bath separation is used for extraction of kernels in the Pioneer Mill and here again a problem arises with *tenera* nuts which is common to all factories. Because of its fibre mantle, the specific gravity of the *tenera* shell is approximately the same as the specific gravity of the kernel and shell tends to float up with kernels during mud bath separation. "Stork" have tried to overcome this by including a fan on the feed into the mud bath from the cracking units.

Air from the fan catches the fibrous mantle on the *tenera* shells blowing this type of shell out but allowing normal shell and kernel to fall into the mud bath separator.

Further Disadvantages of the Pioneer Mill.

1. The mill design is spread out in a horizontal direction instead of being compressed by vertical expansion into a small area and no use is made of gravity feed from one processing machine to another.
2. A lack of conveying systems results in a high useage of hand labour.
3. Single items of equipment are in some cases quite good but are badly linked together.
4. The sterilizer is too small for the factory.
5. At least one more cracking unit is required.
6. Screen sizes are incorrect for the unit in which separation of dust, kernel plus shell and uncracked nuts is affected between the cracking and separation stages.

Some improvement could be obtained by correcting, where possible, the above faults and by replacing all the processing equipment up to the digester stage with "Stork" units.

Oil Quality.

Factory processed palm oil has a free fatty acid content of two to three per cent. Kernels when fresh have a free fatty content of one to one and one-half per cent. but this may rise on storage or if kernels are broken to eight per cent.

Yields.

Yields of semi-wild palms in West Africa vary enormously, usually within the range of 500 to 5,000 lb. of bunches per acre per annum. Estate yields in Malaya are not less than 11,000 lb. of bunches per acre giving not less than 15 cwt. of oil and three and one-third cwt. of kernels per acre per annum. Many estates average over one ton of palm oil per acre per annum. Some average yield figures are shown in Table II.

Table II.

Oil Palm Yields.

	lb. Bunches per acre.	Per Cent. Oil extraction.		Yield in tons oil per acre.
		Bunch.	Fruit.	
West African Wild Palms—				
Native soft oil extraction	2,000	8-1/3	12½	0.07
Pioneer Mill	2,000	13-1/3	20	0.12
West African Plantation Palms—				
Pioneer Mill	6,000	13-1/3	20	0.35
Malayan Deli Plantations	11,000	15-16	25	0.75

ACKNOWLEDGEMENTS

The author would like to thank Dr. Ir. L. D. Sparnaaij, Senior Plant Breeder at the West African Institute for Oil Palm Research, Nigeria, and M. G. Poels, Chief, Division of Oil Palms at Yangambi, in the Congo, for the assistance and information they so readily provided in discussions on the botany and breeding of the oil palm.

Grateful acknowledgement is also extended to Mr. S. C. Nwanze, Research Engineer at the West African Institute for Oil Palm Research, Nigeria, for helpful discussions on the problems associated with the production of palm oil and for the photographs of the "Stork" factory at the Institute.

The paper also includes data supplied by Professor C. C. Webster, formerly of the Imperial College of Tropical Agriculture, Trinidad, and Professor J. W. Purseglove of I.C.T.A. Permission to utilize this is gratefully acknowledged.

REFERENCES

ADU, A. V. (1959). Division of Soil and Land-Use Survey, Kwadaso, Ghana. *Personal Communication.* June, 1959.

ALLEN, J. D. (1954). The effect of cultural treatments on losses in the nursery. *J. W. Afr. Inst. Oil Palm Res.* 1 (2) : 42-45.

ANON. (1953*a*). Notes on establishing an oil palm nursery. *J. W. Afr. Inst. Oil Palm Res.* 1 (1) : 88-92.

ANON. (1953*b*). The cost of establishing an oil palm plantation. *J. W. Afr. Inst. Oil Palm Res.* 1 (1) : 92-94.

ANON. (1959). The transplanting of oil palm seedlings. *W. Afr. Inst. Oil Palm Res. Advisory Sheet* 1.

CHAPAS, L. C., TINKER, P. B. H. and ZIBOH, C. O. (1957). The determination of the oil content of oil palm fruit. *J. W. Afr. Inst. Oil Palm Res.* 2 (7) : 230-236.

GAULT, R. (1953). Methods of germinating oil palm seeds. *J. W. Afr. Inst. Oil Palm Res.* 1 (1): 76-87.

GUNN, J. S. (1958*a*). Agronomy Division. *Sixth Annu. Rep. W. Afr. Inst. Oil Palm Res.* pp. 93-94.

GUNN, J. S. (1958*b*). Agronomy Division. *Sixth Annu. Rep. W. Afr. Inst. Oil Palm Res.* pp. 90-92.

GUNN, J. S. (1960). Agronomy Division. *Eighth Annu. Rep. W. Afri. Inst. Oil Palm Res.* pp. 72-74.

JAGOE, R. B. (1952). The "Dumpy" Oil Palm. *Malay agric J.* 35 : 12-21.

MARYNEN, T. and BREDAS, J. (1955). La germination des graines d'Elaeis. *Bull. Inf. I.N.E.A.C.* 4 (3): 156-176.

MARYNEN, T. and GILLOT, J. (1957). L'elimination des vieux palmiers par empoisonnement. *Bul. Inf. I.N.E.A.C.* 6 (3) : 167-174.

POELS, G. (1959). Institute National Pour l'Etude. Agronomique du Congo Belge. Yangambi, Belgian Congo. *Personal communication.* July, 1959.

REES, A. R. (1959*a*). Germination of Oil Palm seed. Large scale germination. *J. W. Afr. Inst. Oil Palm Res.* 3 (9) : 83-95.

REES, A. R. (1959*b*). The germination of oil palm seed: The cooling effect. *J. W. Afr. Inst. Oil Palm Res.* 3 (9) : 77-82.

SPARNAAIJ, L. D. (1955). Seedling selection in oil palm nurseries. *J. W. Afr. Inst. Oil Palm Res.* 1 (3) : 51-63.

SPARNAAIJ, L. D. (1959*a*). West African Institute for Oil Palm Research. Nigeria. *Personal Communication.* July, 1959.

SPARNAAIJ, L. D. (1959*b*). Plant Breeding Division. *W. Afr. Inst. Oil Palm Res. Seventh Annu. Rep.* pp. 70-85.

SPARNAAIJ, L. D. (1960). The analysis of bunch production in the oil palm. Part IV. *J. W. Afr. Inst. Oil Palm Res.* 3 (10) : 138-155.

TOOVEY, F. W. (1953). Field Planting of oil palms. *J. W. Afr. Inst. for Oil Palm Res.* 1 : 68-75.

WEST AFRICAN INSTITUTE FOR OIL PALM RESEARCH (1954). *The West African Institute for Oil Palm Research.* Lagos: Nigerian Information Service. 80 pp.