A Study of the Malaysian Oil Palm Industry, with Reference to possible Development in Papua and New Guinea.

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ABSTRACT.

Even though large areas of fertile land with a suitable climate are available, no commercial planting of oil palms has been undertaken until very recently in Papua and New Guinea. The high capital requirement to set up a plantation and processing factory has been the main inhibiting factor. The very high and relatively quick returns from oil palms, combined with stable prices and sound market prospects, make this a most attractive crop for the Territory.

The industry in Malaysia is as advanced as anywhere in the world, and the factors contributing to this are examined. Good economic conditions and a favourable environment have stimulated the development of improved management techniques and planting material. The new tenera *material now being released is capable of very high yields. Improved germination and nursery techniques, assisted pollination and heavy fertilizing based on foliar analysis can all be used to achieve these yields. The use of leguminous cover crops and effective weed control also plays an important part, together with control of diseases such as* Ganoderma *Basal Stem Rot, and pests such as the Rhinoceros beetle.*

As well as obtaining high yields, there is much scope for keeping production costs low by using an efficient estate layout, by streamlining and mechanising of harvesting and other operations, and by efficient mill design and operation.

INTRODUCTION.

THE oil palm, *Elaeis guineensis* Jacq., is one of the world's major sources of vegetable oil. Its yielding ability is well above all other oil crops, especially when grown under good environmental conditions as in Malaya, and with modern genetic material. At an Oil Palm Conference conducted by the Tropical Products Institute (1965) it was considered that all palm oil entering world trade, for as far ahead as it is possible to foresee, should meet a ready market. The world price for palm oil has been mainly above $A200 per ton for many years, and is particularly stable due to the versatility of the oil in its many industrial uses. The price for palm kernels follows copra prices closely; the two having similar uses.

With large areas of land in Papua and New Guinea likely to be eminently suited to this crop, future development may be of great importance to the economy. The industry in Malaysia is expanding very rapidly at present, and is in a very strong position. Much can be learned from results and experience obtained there, with conditions similar in many ways to Papua and New Guinea. It is the intention of this paper to discuss the industry, emphasising these aspects of research and estate practice likely to be most applicable to this country.

Malaya had about 130,000 acres of oil palm in 1960, producing 120,000 tons of palm oil. Since then the increasing interest in the industry, sound economics and improved management techniques and planting material have combined to cause a rapid expansion in acreage and productivity. The planted acreage will pass 200,000 in 1966, and will continue to expand if the economic climate remains favourable. Gray (1963) gives the average yield of eight to ten year old Deli *dura* palms on the fertile west coast clays of Malaya as 1.5 tons of oil per acre per year, and many cases of fields producing more than two tons were noted. The improved *tenera* material planted in recent years should give considerably higher yields than this. Large areas

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of coconuts and rubber, as well as new forest areas, are being replanted with oil palm, particularly on coastal soils. The coconut cannot compete with the oil palm on a well organized estate, and rubber produces its best yields on the better drained inland soils, where oil palm yields are usually lower (Gray 1963). The Malayan climate, with sunlight and rainfall plentiful and well distributed throughout the year, appears to be ideal for the oil palm ; much higher yields being obtained than in West Africa, where the palm is indigenous.

For efficient production, large scale processing is necessary, as with sugarcane, and it is generally held that the desirable minimum sized mill is one that will handle fruit from about 3,000 acres. The large expatriate companies have been the main planters in Malaya, with estates normally of 5,000 acres or more (*Plate* I), but settlement schemes run by the Federal Land Development Authority are of increasing importance. There is none of the West African type of smallholder production with fairly primitive production methods, mainly 'natural' palm groves and much home consumption of the produce.

Possible types of development for Papua and New Guinea would be either full scale estates operated by a large company, organized smallholder schemes, or small estates supplying a central mill and owned by individuals or smaller companies. A combination of these types may be the best way to begin an industry, since processing is normally more efficient with a large mill and fruit can be transported economically from 25 or even 50 miles away. The International Bank for Reconstruction and Development has suggested in its report (1965) the combination of nucleus estates and smallholder schemes, similar to that now being employed for tea in the Highlands.

Publications dealing with the oil palm industry in Malaya have been few until recently, but this position is changing, and several books are due to appear shortly. One, "The Oil Palm In Malaya" (Department of Agriculture, Malaya, 1966), deals broadly with the subject, and another, "Planting Techniques for Oil Palms in Malaysia" (Bevan, Fleming and Gray 1966) deals more directly with practical aspects.

All currency figures mentioned in this paper are in Australian dollars.

BOTANY AND BREEDING.

The oil palm is monoecious, producing alternate phases of male and female inflorescences on the one palm. A new frond is produced about every 14 days and may bear in its axil a male or female inflorescence or occasionally a bisexual one when sex phases are changing. Each female

Plate I.—Part of a large oil palm estate in Southern Malaya.

inflorescence may bear 1,000 to 1,500 individual flowers, and each male many times this, but the whole structure is normally referred to as a ' flower '. The ratio of the number of female to total flowers in a given area is called the sex ratio, which is strongly influenced by environmental conditions, and tends to be lowered by any form of stress on the palm. Lack of female flowers tends to be a factor limiting yield in West Africa whereas lack of male flowers may be the main problem in Malaya, especially with young palms, leading to the use of assisted pollination techniques as an estate practice in many areas.

The fruit takes between five and six months from pollination to maturity. Palm oil is produced from the yellow fleshy mesocarp of the fruit, and the other main product is the palm kernel, which has similar properties and uses to copra. A hard shell, or endocarp, separates the two.

The varieties of the oil palm were described by Newton (1961). The most important classification is on shell thickness, the *dura* having a thick shell, the *tenera* a thin shell, and the *pisifera* no shell at all. The *tenera* type is a hybrid between the other two, and self pollinating a *tenera* will give *dura, tenera* and *pisifera* progenies in a 1 : 2 : 1 ratio, shell thickness being simply inherited. The oil palm industry in Sumatra and Malaya was based on a variation of the *dura* type, the Deli, which has a much thicker mesocarp, and hence produces more oil.

The tenera material now being grown commercially in Malaysia is derived from high yielding Deli *duras,* and *pisiferas* of Sumatran and African origin with a small proportion of Deli ' blood '. The female parents in the hybrid cross are the Deli palms since most pisiferas produce viable pollen but do not set fruit well. Pollen from the selected pisifera parents is dusted onto the receptive female flowers, with a number of precautions such as bagging the flowers being taken to avoid contamination from outside pollen. A good Deli *dura* (*Plate* II) may have 60 to 70 per cent. of the clean fruit as mesocarp, and 21 to 30 per cent. as shell, whereas a typical African *dura* may have about 46 to 56 per cent. mesocarp and 30 to 37 per cent. shell. *Teneras* produced initially from this African material will also tend to be of low quality, with about 55 to 65 per cent. mesocarp and 17 to 24 per cent. shell, whereas good commercial teneras in Malaya now have 75 to 85 per cent. mesocarp (Gray 1964 and personal communication). African *teneras* are being introduced into breeding programmes mainly because of their greater variability, and hence value in a long term breeding programme. It is expected that initial plantings in Papua and New Guinea will be all Malayan commercial tenera.

The Deli *dura* will normally give an extraction rate of about 17 per cent. oil in F.F.B., or fresh fruit bunches, whereas commercial *teneras* are now giving 22 to 24 per cent. Breeders claim that this can be lifted to 30 per cent. within four generations, or 30 years, which at 10 to 12 tons F.F.B. per acre would be a most attractive proposition.

Much breeding work in the past has centred around breeding short statured types, particularly using the ' dumpy ' mutant of the Deli strain. However, the emphasis has shifted now to breeding high yielding teneras which come into full bearing at an early age, and which will probably be replanted at 20 to 25 years, before height is a limiting factor to efficiency of harvesting. The older Deli types were slow in coming into full bearing and still produced a worthwhile crop at 35 years, so replanting tended to be delayed as long as possible. Also, the availability of new high yielding material makes early replanting especially desirable now.

CLIMATE AND SOILS.

The oil palm is best suited to equatorial or wet tropical lowland conditions, with the amount and distribution of sunlight and rainfall being most important features.

While a minimum of 70 in. annual rainfall is often quoted, and the best oil palm areas are usually in the range 80 to 120 in., the distribution is usually more important than the total. The lower limit of the ideal distribution will be very much influenced by soil type; heavy soils tending to modify the severity of a dry season. On most soils a dry season of about three months with a minimum monthly rainfall of 2 to 3 in. would be satisfactory, but palm yields on light sandy soils under these conditions may fluctuate more over the year, and perhaps be lower overall, than would be the case on Malayan coastal clays.

Plate II.—A good Deli *dura* palm being used as the female parent for commercial seed production. The female inflorescences have been bagged to prevent contamination by unwanted pollen during the receptive period.

The amount and distribution of sunlight should be considered in conjunction with rainfall figures. Measurement of sunlight as "hours of bright sunshine" is a useful guide, and desirable oil palm areas generally have 2,000 hours or more per year, with preferably not much below five hours per day in the minimum month.

The climate of Southern Malaya fits the above criteria very well, resulting in high yields, whereas the West African oil palm belt has a much less favourable climate, with a long distinct dry season and very low sunshine figures of less than three hours per day in several months of the wet season. Yields are mostly less than half those obtained in Malaya, with a greater seasonal fluctuation (Michaux 1961).

Oil palms are usually grown within 1,000 ft. of sea level, depending on latitude and local climate modifying factors, such as in the Congo basin where the main palm areas are at an altitude of between 1,200 and 1,500 ft. A temperature range of 65 to 90 degrees F., with a normal diurnal range of 70 to 88 degrees, is regarded as close to optimum. It may still be economic to grow palms under a wider temperature range, such as at higher altitudes or latitudes, but the effect of lower temperatures is usually seen as lower rates of growth and yield. Yields in the Congo are considerably lower than in Malaya, most probably due to lower night temperatures.

In selection of oil palm soils in Malaya, most emphasis is laid on soil physical properties and topography, with chemical fertility relatively less important. Rooting depth is one of the main criteria, and soils with a hard laterite band at less than 3 ft. are usually rejected. Coastal soils with a permanent water table at 2 ft. are considered marginal unless they can be drained, 3 ft. being usually considered quite good for the shallow rooting oil palm. A layer of up to 2 ft. of peat over the clay is considered satisfactory, particularly if the palm is planted in a hole to get its roots into the clay subsoil as quickly as possible.

Soil texture is of lesser importance, and any soil not subject to severe drought under the prevailing rainfall conditions would be considered suitable. The two main soil types used are the marine alluvial coastal clays, and the 'inland' soils which are red and yellow latosols and podsolics derived from granite or sedimentary rocks (Panton 1964). The granites have been the most used inland soils so far, and the sedimentary soils are of more variable fertility. One of the principal inland soils is granite derived, with a thin surface horizon of sandy loam and at least 4 ft. of sandy clay loam subsoil (Null, Acton and Wong 1965).

A slope of 12 degrees is considered marginal for a large area, although many estates have small areas of greater slope. The main problem on steep slopes is harvesting and fruit evacuation.

Most Malayan soils are quite acid. The coastal clays, which produce the highest yields, often have a pH of 4.0 to 4.5, and the inland soils about 5. The optimum for oil palms is often quoted as 5.0 to 5.5 and, with the shortage of data on oil palm yields on neutral and alkaline soils such as many in Papua and New Guinea, care will have to be exercized. Nutritional problems may be quite different on these types of soils.

Where the climate, topography and soil physical properties are suitable, then the highest fertility soils are preferred for development. The heavy yielding oil palm makes such strong demands on soil nutrient reserves that fertilizing is essential on most soils, at least after bearing for a few years.

Fertilizer use has been quite light on the coastal clays, so far, these having shown unusual powers of supplying nutrients, particularly potassium, but palms on a number of these soils are now responding to a range of nutrients (Gray 1963). On most other soils, fertilizing is now a routine practice, responses being found to many elements. Even poor soils, such as deep peats, can give good yields when properly fertilized, and it seems that initial soil fertility may not be of great importance. The ability to supply nutrients over a long period, and to use applied nutrients may be of greater significance.

GERMINATION.

The natural rate of germination of oil palm seeds is very low and many methods have been devised to increase this, mostly involving keeping seeds warm and moist until they germinate [Rees 1960(*a*)]. In Malaya, seeds were sown in sandbeds, which were hand watered, relying on solar radiation for heat, whereas in West Africa the best methods were based on the W.A.I.F.O.R. developed electrically heated germinating chambers (Rees 1959).

The best method now is the 'dry heat' method which is being used extensively in Malaya, and involves heating the seed at 38 to 40 degrees C. in one of these germinating chambers, but at a moisture content of 16 to 18 per cent. of dry weight, which is too low for germination. Rees [1960(*b*)] showed that the high temperature requirement of oil palm seed could be fulfilled at a low moisture content. The standard method now is to heat the dry seed in sealed polythene bags for about 40 days for seed that has been stored after harvest for about four months, or somewhat longer for fresher seed. Seeds are then soaked to bring them up to the required moisture content, which is about 22 per cent. for *tenera,* and then kept moist in sealed polythene bags until they germinate. Normally 85 to 95 per cent. should germinate within a month of soaking, whereas with the older 'wet heat' method 80 per cent. germination within three months was considered good. The wet heat method also gave a high incidence of 'Brown Germ', a fungus infection of the germinating seed.

Seed can be supplied by the main Malayan producers either fresh, 'preheated' with dry heating but not soaking carried out, or 'pregerminated' ready to plant. Pregerminated seed is supplied to most estates now, and this is probably the best method if transport can be arranged, and receiving facilities on the estate are adequate. Seed for some of the new estates in Sabah was airfreighted from Malaya, and this may be possible for Papua and New Guinea also, but if not, preheated seed can be used. Seed recently imported to the Territory has been sent by air in this form, and can be kept for about 30 days before soaking, or longer if maintained at about 15 per cent. moisture content.

Germinated seeds are removed during weekly inspection of the polythene bags, and these are kept moist for a further seven to ten days in sealed bags until the root and shoot can be clearly distinguished. The shoot is short and sharp, whereas the root elongates first, and has a blunt end covered by a rough root cap. Seed can be kept for two or three weeks after germination if handled carefully. 'Twins', or seeds with two germinating embryos, are best handled by rubbing off one, rather than trying to grow both seedlings and later separating them.

NURSERY TECHNIQUES.

The main methods now being used in Malaya are the older, though still widely used field nursery, and the more recently developed system using polythene bags. The field nursery is established by planting out young basketted seedlings at a 3 ft. spacing in a suitable area (*Plate* III). When palms are old enough to be planted out, they go through a root pruning process before lifting and transport to the field. The main polythene bag method until recently has been to grow seedlings to the four-leaf stage in small polythene bags as a prenursery and then transplant to larger bags for the main nursery stage. More recent work indicates that it may be desirable to plant germinated seed straight into the large polythene bags, and eliminate the prenursery.

The field nursery method is not really suitable where no clay soils are available, as it depends on being able to dig the seedling out in a block of earth which will then hold together until it can be planted in the field. A number of small trials have indicated that there is substantially increased early growth in the field from polybag palms compared to field nursery palms, probably due to a reduction in transplanting shock and elimination of root pruning.

Even without considering the growth differences, many people claim that the other advantages of the polybag system, such as simplified management and easier and more flexible arrangements for field planting, make it well worth while adopting as standard. The polybag nursery can be on a permanent site with an irrigation system installed (*Plates* IV and V), and the whole nursery and field planting operation can be independent of weather conditions. The field nursery must normally be shifted each year to avoid soil-borne diseases. Polybag seedlings can be transported easily, and the nursery spacing can be adjusted from close initially to conserve moisture to a wider spacing when the fronds begin to mesh. Nursery costs with the two methods up to field planting have been similar.

Plate III.—A field nursery. The palms in the background are about 35 years old, and due for replanting.

The Polythene Bag Method (no Prenursery).

This method, as developed by the Harrisons and Crosfield Research Station, eliminates the prenursery, as recent trials have shown quite marked improvements in growth, and at least two months should be saved. Uninterrupted growth is apparently desirable from germination to field planting ; any disturbance such as the transplanting from the prenursery acting as a check on growth.

The polybags should be 15 x 20 in., and of .005 gauge polythene, with holes punched on the lower half. These are filled with loam top-soil ; about 35 lb. per bag. A clay loam soil is preferred, as a sandy loam can be too free draining, possibly increasing susceptibility to Blast disease. The seed is planted in a small hole in the soil surface, orientated with the root pointing down and the shoot up, and covered with about half an inch of soil. A twisted seedling will result if the seed is planted up-side-down.

Light temporary shade should be provided until the seedlings are at the two-leaf stage, when it can be gradually removed over a two-week period, leaving them exposed to full sunlight thereafter. Seedlings should be watered daily, either by hand or with a sprinkler system. The young seedlings can be fertilized by watering with a 1 per cent. urea solution, washed off the leaves with water. After about the four-leaf stage, half to one ounce of one of the compound NPKMg fertilizers or a similar nursery mixture can be applied per month, increasing to 2 oz. after about seven months.

Nursery selection is highly regarded in Malaya, up to 30 per cent. of seedlings often being discarded. Obviously poor types can be removed after a few months, the main ones being ' grass leaf ' types with long, narrow, rolled leaflets, and those with twisted leaves, usually planted up-side-down. A final selection is then made before field planting, the following being the main additional types rejected :—

1. Runts ;
2. Sterile types, usually with acute angled leaflets and a coarse habit of growth ;
3. Types with leaflets either very widely spaced, or bunched together, at the end of the frond particularly ;
4. ' Flat top ' types, where the centre leaves have not grown as well as the outside ones ; and

5. Those with leaflets still fused together after about nine months, referred to as 'idolatrica' types.

Prenursery Method.

This has been the main polybag method used until recently. Germinated seeds are planted in 6 x 9 in. polybags, and raised in these to about the four-leaf stage, when they are transplanted into larger bags, using a similar technique to that described below for the planting of large bag seedlings in the field. The method is otherwise very similar to that already described. Space, labour, water and fertilizer are saved in the early stages, but this appears to be more than offset by the retarded growth.

Pest and Disease Control.

No spraying should be done before the first seedling leaf has developed, or injury may result. Outbreaks of leaf spot diseases can be controlled if recognized at an early stage, and sprayed at weekly intervals, with Captan or Thiram at 0.2 per cent., until new growth is free from infection (P. D. Turner, personal communication). An insecticide such as dieldrin can be used for caterpillar or other leaf eating insect attacks. Red spider outbreaks should be treated with an acaricide such as Tedion or a systemic insecticide such as Rogor or Metasystox, as dieldrin may only increase the pest.

'Blast' (see diseases section) must be guarded against by adequate watering and possibly shading, as the disease can be very severe, causing heavy losses in polybag nurseries.

FIELD ESTABLISHMENT.

The normal method of clearing forest is hand felling, then stacking and burning. If the cover is light secondary forest or grass, burning may be better avoided, especially on light soils. The palms and cover crop are planted among the logs, which are rearranged as much as possible to give the required spacing. Where logs are too heavy to shift, the planting points are adjusted in one direction only, to try and keep lines straight at least one way. If timber can be handled by a bulldozer, it may be desirable to clear it into, for example, every second row space, enabling mechanized maintenance and speeding up other operations. If this is not done, paths may need to be cut along alternate interlines by removing sections of logs with a chain saw, normally just before harvesting starts.

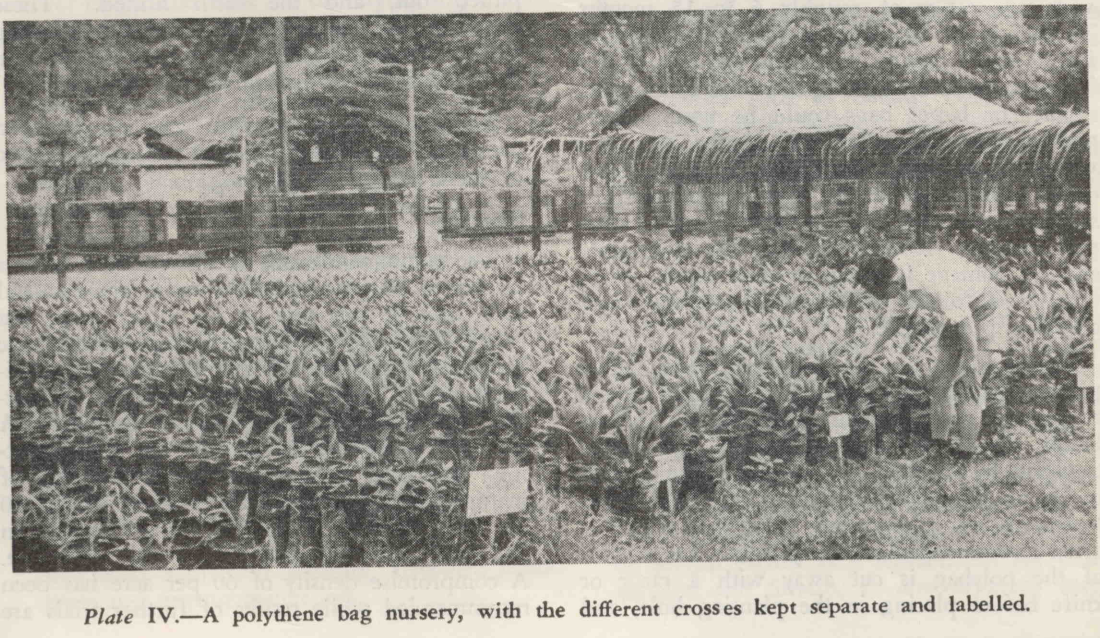

Plate **IV.—A polythene bag nursery, with the different crosses kept separate and labelled.**

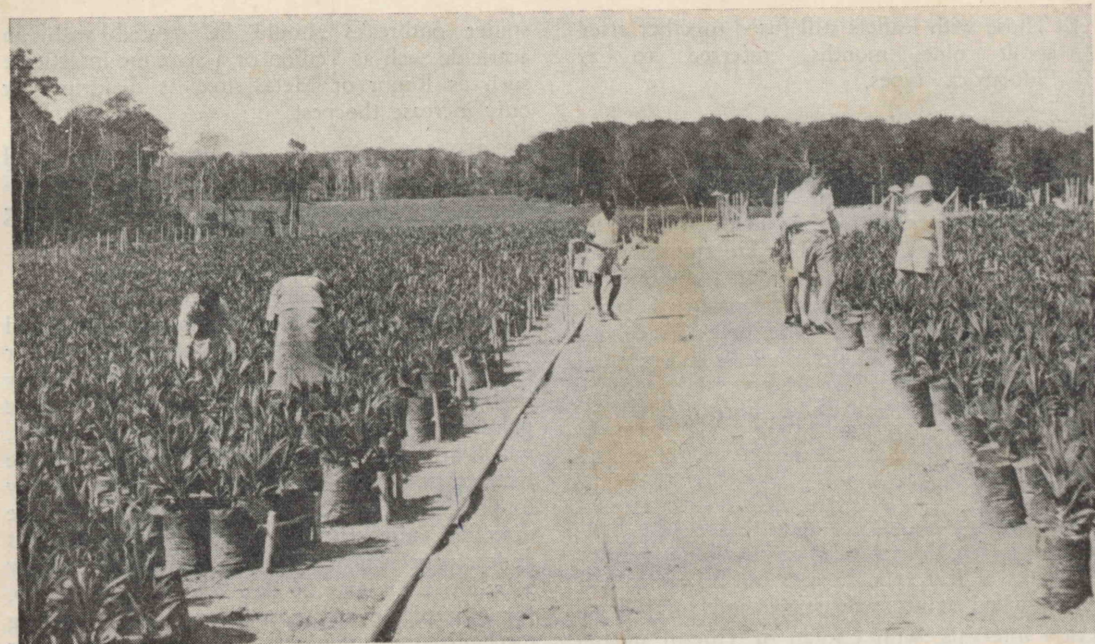

Plate V.—A large nursery with water supply installed. An area of established cover crop can be seen in the background.

Planting.

Field planting can be done with palms over a wide age range of roughly 6 to 15 months. The 15 x 20 in. polybag should be adequate for 12 to 14 months growth in the nursery, but if earlier or later planting than this is intended, smaller or larger bags could be used. Palms planted at earlier than 12 months may give very good results, as found by Gunn and Sheldrick (1963) in Africa with seven-month-old seedlings, but they may be liable to rat or other pest damage. If early planting has to be done and rat damage is likely or does occur, strong wire mesh collars can be used, combined with a baiting programme.

Several times in the last few weeks before planting bags should be lifted and turned around to prevent roots growing into the soil below. Palms should be watered heavily just before transport to the field. The planting hole needs to be no bigger than to take the polybag on light soils, but a larger hole filled with topsoil is often recommended on heavy soils. The bottom of the polybag is cut away with a razor or knife before placing in the planting hole, and then the side of the bag is slit. Earth is filled loosely around the bag which is then carefully pulled out, and the earth firmed. These measures are taken to minimise transplanting shock. Palms should be planted no deeper than in the nursery, or growth may be retarded.

Replacing of undesirable types or damaged palms, or 'supplying', is usually done up to two or three years from planting.

Spacing.

The recommendations in Malaya have been a density of 49 per acre on the more fertile coastal soils, and 55 per acre on the inland soils, but recent Harrisons and Crosfield experiments have indicated that while this may give near to maximum yields from mature palms, early production can be improved by closer spacing. A standard density of 58 per acre (9 meter spacing) was used in Sumatra. While the yield of mature palms may vary little between 40 and 70 per acre, there is a close to linear increase in total yield for the first ten years over this range. A compromise density of 60 per acre has been recommended while results of further trials are awaited, and this would probably be the best for Papua and New Guinea also, giving a 29 ft. triangular spacing. It seems that conditions of less sunlight and higher soil fertility tend to make wider spacings more desirable, and the relative importance of the two in an area will influence the optimum spacing.

It was thought that thinning of an initially denser stand would be desirable, but further work showed that the stand took at least two years to recover, and that thinning is probably uneconomic.

COVER CROPS.

Most rubber and oil palm estates in Malaysia use leguminous cover crops, at least in the first few years after planting. The general policy is to sow a cover mixture, usually *Pueraria phaseoloides, Calopogonium mucunoides* and *Centrosema pubescens*, and to maintain this carefully with a thorough weeding programme (*Plate* VI). As palms grow up and shade out the legumes, usually in five to seven years, the policy is switched to keeping a natural cover free of noxious weeds, and usually maintaining it by hand slashing.

Many reasons are given for this emphasis on cover crops, and these are of varying importance under different conditions.

1. *Weed Control.* If this is the major purpose of the cover, the alternatives of hand, or mechanical slashing of a grass cover should be considered, as legume covers are expensive to establish. Pueraria seems to require more maintenance to keep it as a pure stand in Malaya than it does in Papua and New Guinea, and this may mean that the weed control function is of less value in Malaya.

2. *Pest Control.* Covers have been shown to play an important part in Rhinoceros beetle control. The number of larvae found in logs under covers is very much less than that in exposed logs and it seems that beetles cannot find breeding sites.

3. *Soil Cover and Erosion Prevention.* This is especially important in hilly country, and with light soils subject to washing, structure breakdown and organic matter loss.

4. *Effect on Soil Fertility.* All legumes do not necessarily have a positive effect on yield, and even the proven species need effective nodulation before they can make any contribution to nitrogen nutrition of the palms. Experiments on the coastal clays (Harrisons and Crosfield Annual Report, 1963) have shown the creeping legumes to give the best yields followed closely by bushy legumes, then grass and the native fern *Nephrolepis biserrata,* with the common broad-leaved weed *Mikania scandens* giving very poor results, similar to *Stylosanthes gracilis. Mikania* has been shown to have a growth inhibiting effect (Wong 1964), whereas Stylo appears to be strongly competitive for water and nutrients. It appears that under these conditions use of a cover crop including creeping and possibly bushy legumes will give best results. If the yield losses with a cover such as mechanically slashed grass can be made good economically with fertilizer, then it may be better not to use legumes.

The method generally used in Malaya to establish a first class cover is to clean weed the area first, and then sow the legume mixture in about three rows down each palm interrow. The seed is inoculated with the appropriate *Rhizobium* strain, and sown with a starter dose of fertilizer. The area is kept clean weeded until the legumes are established, usually about two months, and then selectively weeded until a good cover is obtained. After the first year, selective weeding is confined to removal of undesirables such as Lalang (*Imperata cylindrica*), Mimosa, Mikania and woody species. Circles of about 6 ft. diameter around young palms are normally kept clean weeded and clear of cover crop.

Species.

Pueraria phaseoloides has been the main legume used, and has generally given very good results, in estate practice and also in experiments, where it has been used as a standard to judge other covers by, as in the experiments mentioned above. It is slow to establish though, and *Calopogonium mucunoides* is usually used with it to give a quicker early cover. *C. caeruleum* is a promising alternative. *Phaseolus sublimatus* and *P. calcaratus,* both annuals, were seen used on several estates as a replacement for Calopogonium, and Siratro, *P. atropurpureus* may be

Plate VI.—An area of young palms with a good leguminous cover crop.

even better. *Centrosema pubescens* is commonly the third component of the mixture, and forms a useful addition to Pueraria in the permanent cover. *Desmodium ovalifolium* is very similar in habit to Centrosema, and is probably more shade tolerant. It was seen to be vigorous on several estates in Sabah and may be a useful alternative to the virus susceptible Centro in Papua and New Guinea.

The bushy *Flemingia congesta* has been shown in the experiments mentioned to have almost as good an effect as Pueraria on crop yield. It has rather uneven germination and is slow to establish, but produces a large quantity of mulch and suppresses weed growth well. A definite reduction in Rhinoceros beetle damage has been shown over treatments with creeping covers, if it is allowed to grow to 4 or 5 ft. This is apparently due to restriction of the beetles' flight as well as a reduction in potential breeding sites. Flemingia is sometimes used in a mixture with Pueraria, especially if beetle damage is likely or regular weeding doubtful, but it should not be sown on or near harvesting paths. *Tephrosia noctiflora* has similar characteristics to Flemingia, but is quicker to establish, faster growing and less permanent.

Stylosanthes gracilis, as mentioned above, has had a fairly severe effect on palms, due apparently to a combination of moisture and nutrient stress, with the former more important on lighter soils and hilly ground, and the latter on the coastal clays. In most trials the seed was not inoculated with the approved *Rhizobium* strain, and much of the nutrient stress may be due to lack of nitrogen fixation. Stylo also puts down a deep taproot from the seed, and then more shallow roots from the nodes as it spreads, and propagation from cuttings may eliminate much of the moisture stress effect. It could be a valuable cover, as it is very easy to establish and maintain.

Upkeep in Mature Areas.

As mentioned, the cover crop is eventually shaded out, and a natural cover is usually maintained by hand or mechanical slashing with removal of undesirable species. A special point is made of eradicating lalang. The main method used was to spray sheet lalang with sodium arsenite, but the use of dalapon followed a few weeks later by paraquat is often recommended now. Small clumps can be eradicated by spot spraying, forking, or wiping with lalang oils. When harvesting starts, usually in the third year, paths are cut down alternate interlines, and these are kept clean weeded together with a circle around each palm about 8 ft. in diameter. Upkeep methods used are hand weeding, herbicides or both ; the decision as to which method to use being mainly based on costs. Herbicides are mainly used in Malaysia, and the principal one used in the past was sodium arsenite. This is very dangerous to users, and a newer method employing a combination of paraquat and amitrole is now being used on many estates (Headford 1965). The usual procedure is to spray amitrole first, at two pints per sprayed acre in about 20 gallons of water, and then two to four weeks later spray paraquat, at the same concentration. The formulations used of both these herbicides have 20 per cent. active ingredient. Two of these treatments per year should be adequate, and even just one double spraying and one or two single applications of one pint of paraquat may be enough in mature areas with fairly heavy shade.

CASTRATION.

The removal of male and female inflorescences on very young palms before they have matured or set fruit is a growing practice in Malaysia. The main reason why this is being done is that any bunches produced before about 30 months in the field are very small, have a low oil content and are expensive to harvest, as a large area must be covered to cut a few bunches. These bunches are also rarely pollinated properly, making the palm susceptible to attack by *Marasmius palmivorus,* a fungus which destroys bunches (see diseases section). Infrequent harvesting also encourages rats.

Palms are castrated monthly from about 14 to 26 months on many Harrisons and Crosfield estates, and thus the first crop comes in evenly at 31 to 32 months. Returns are most probably increased over the first few years, and at least little or no crop will be lost. Castrated palms also have sturdy vegetative growth, with a thickened trunk.

The effect of castration on commercial areas has been generally to produce a large number of female flowers after the treatment ceases, and hence increase the need for assisted pollination. Prolonged castration, when ceased suddenly, leads to a very large number of bunches in the first few months cropping which can in turn lead to over-stressing and the palm may enter an extended male phase. If prolonged castration is carried out, it seems that the palms should be allowed to come into production more slowly by partially castrating for a period, where only a limited number of bunches are allowed to develop.

While the need for assisted pollination may be increased by castration, the treatment is likely to be building a palm which, with an adequate nutrient supply, can stand up to the heavy early cropping that assisted pollination ensures, without undesirable effects on the sex ratio or later bearing life of the palm.

The case for relatively mild castration up to about 26 months seems well established, but more prolonged castration is probably only desirable on new estates. It is not usually economic to begin factory operations before the first year's planting is about four years old, and hence castration may be carried out up to 42 months if no alternate processing facilities are available.

Experimental work on castration has been limited, but a small Harrisons and Crosfield trial running since 1960 has shown no adverse effects on the palm. More critical experiments are just starting to produce results, and data on castration combined with assisted pollination and fertilizers should be forthcoming shortly.

ASSISTED POLLINATION.

The sex ratio of young palms up to about eight years old tends to be very high in Malaysia, which means a low rate of male flower production, causing low and uneven fruit yields. The reasons for this appear to be a combination of good environmental conditions and high yielding modern genetic material. The effect of the poorer climate in West Africa has been mentioned, drought particularly increasing the number of male flowers, and low sunlight inhibiting formation of female flowers. Soil fertility also has an effect and the problem in Malaya appears to be less acute on the poorer inland oils, though the increasing use of fertilizers is probably making pollen shortage a limiting factor on the yield of young palms there too. Generally it seems that some form of stress on the palm, such as that caused by low sunlight or soil moisture, less fertile soils, close pruning and heavy bearing, will produce a lower sex ratio.

Almost entirely female flowers are quite often produced initially on new estates or large new plantings in Malaya. Unless outside pollen is brought in, these bunches will be unpollinated and palms may produce female flowers indefinitely. Not only will no fruit be produced, but also an attack by *Marasmius* is likely, and this is expensive to eradicate and has a severe effect on the palm. If assisted pollination is carried out, fruit setting, which imposes a stress on the palm, takes place and quite quickly some male flowers are produced.

Gray (1966) discusses an experiment carried out to determine the effect of assisted pollination on yield and other palm characteristics. Unfortunately for the experiment, over the total five-year period male flower counts were not really low, and hence the yields over the whole period were not significantly greater with assisted pollination. Four, eight and twelve pollination rounds per month were compared with a natural pollination control, and commenced on three-and-a-quarter-years-old Deli palms. The main effect on bunch yields was to even out the large fluctuations over the year as obtained in the control treatment, a very desirable effect for factory and estate organization. When the peaks and troughs of yield in the control treatment were compared with male flower production five months earlier, a close correlation was obtained, indicating the direct effect of pollen availability on yield. Bunch weights in the pollination treatments were increased but a reduction in frond production and increase in inflorescence abortion gave a lower number of bunches. Pollination had a marked effect on the sex ratio, with the most intense treatment producing 40 per cent. more male flowers than the control over the whole period.

Several larger experiments with less danger of outside pollen masking the treatment effects, and sited in areas more liable to low male flower production are underway. It is hoped to more closely simulate estate conditions, where large areas of palms with really low male flower production occur, and where very substantial yield increases are obtained with routine assisted pollination.

Assessment of the need for Assisted Pollination.

The experiment referred to above indicated that male flower production at the time female flowers are receptive has a direct effect on yield. Actual pollen availability is then determined by male flower number and distribution, modified by weather conditions. This has been used for some years on estates in assessing the need for pollination, in conjunction with inspection of the actual fruit set obtained, and a number of ways of estimating male flower production are used. A commonly used ' rule ' is that pollination is necessary if less than 15 male flowers are produced per acre per month in areas over about five years old. Sometimes a higher figure is used for younger areas, with flowers close to the ground and more screening by fronds. Another rule used was that if all male flowers in an area, both ripe and pre-ripe, are counted at the one time, less than about 18 per acre may indicate a need for pollination. Of the 18, about six would be ripe and shedding pollen.

The number of palms producing male flowers may be a better guide to availability than just the number of flowers, since production can be all from a few palms, and the wind borne pollen apparently does not travel effectively more than about 100 ft. Distribution over the area rather than total quantity may be the problem. One figure quoted was that assisted pollination could probably be ceased when about 40 per cent. of palms are producing male flowers.

The characteristics of the aerial environment, namely windspeed, temperature, humidity and rainfall, modify pollen availability at any one time. The 100 ft. distance mentioned for effective pollen travel is under normal low windspeeds on the West Coast of Malaya, and more air turbulence will increase the range and effectiveness of pollen distribution. Diurnal pollen distribution, as measured with a Hirst Spore Trap, tends to follow the temperature curve directly and the humidity curve inversely. In other words, pollen is most available on warm sunny days, and least on rainy days, and at night. Some people claimed that best fruit set was obtained in the drier months, due to increased pollen availability rather than more male flowers.

If the relationships between male flower number, weather conditions and fruit set are known, an intelligent assisted pollination programme can be applied. The success of fruit set can be determined as early as two weeks after pollination, when the developing fruit has a squat, glossy appearance, whereas with initial parthenocarpic development, the unfertilized 'fruit' is narrower, and dull black.

On palms of five to eight years old, pollination may have to be done for eight months of the year or less, whereas younger palms may require it for the full 12 months. One estate on fertile volcanic soils has been regularly recording less than five male flowers per acre per month on three to four year old palms, indicating a need for year round pollination. These sort of levels are likely in Papua and New Guinea under similar conditions of good soil and climate.

Practical Application.

A number of trials have been carried out testing various devices for pollen distribution, but the simplest has so far proved to be the best. It consists of a small plastic bottle with some form of perforated lid, such as a piece of muslin stretched across the top. Pollen is dusted onto the receptive inflorescence by shaking or squeezing the bottle, and this is often called the 'pepperpot' method (*Plate* VII). When palms have grown too high for bunches to be reached, at about six years old, a variety of devices are used, such as one with an aluminium tube and rubber bulb.

Since the female flower is receptive for about three days, pollination rounds will have to be done this often if all bunches are to be fully pollinated, and where no natural pollination occurs. In practice about eight rounds per month is adequate, with less than five rounds usually of little value.

Pollen is usually obtained the previous day by cutting off male flowers, and drying either on a sheet of paper in the sun, or in a simple oven, with for example electric light globes to supply the heat. If in short supply, it can be diluted by using ten parts talc to one part of pollen. If pollen is likely to be in short supply for a programme, as on a new estate being planted up quickly, a 'pollen garden' can be established. An area of palms planted densely at about 15 ft. spacing, and pruned heavily, will produce mainly male flowers. If this source is relied on for all pollen supplies, about 3 per cent. of the estate area may have to be used, and the planting of at least a few acres has been recommended for some new estates.

With an efficient system, costs have dropped from about 8c per acre per round to less than 4c, which at eight rounds per month over the whole year is about $3.75. This is the total cost, including collection of pollen. One of the reasons for the cost reduction is that pulling back the sheaths surrounding the female flower was shown to be unnecessary, and now pollen is just dusted onto inflorescences which look to be receptive, without a close inspection. It does not matter if some are done twice. The usual practice is for the pollinator to scratch his initials and the date on the frond base subtending the pollinated flower, and this too can be omitted, though it does serve as a check on work.

An Alternative.

On a number of new Harrisons and Crosfield plantings, an alternative or at least addition to assisted pollination is being tried, and involves planting extra palms for the sole purpose of supplying pollen. An extra palm is planted 12 ft. in the row from every fourth palm in every fourth row, giving close to four extra per acre. The close spacing should encourage male flower production in both palms at each point, and the extra palm will be pruned heavily. Even if this treatment is not fully effective, it should at least cut down the amount of hand pollination required, and the extra palms can also be used as a source of pollen. Every palm will be within about 60 ft. of one of these 'pollinator palms'. After about eight years, or when the need for the extra palms is past, they can be cut out.

FRUIT RIPENING AND HARVEST.

The process of fruit harvesting and evacuation to the mill usually represents up to two-thirds of the annual field running costs on a mature estate, so the importance of an efficient system is obvious. The efficiency will be determined by the yielding characteristics of the palms as influenced by age and season, and by the estate layout, equipment and labour used.

Variation in Yield.

The yield variation due to age of the palm will follow a pattern such as that given below, based on figures for some of the early D x P material on average inland soils in Malaya (Chemara 1964), with estimates after the sixth year.

With more fertile soils and new D x P material, yields should be higher, and reach an earlier peak.

The effect of the environment on the sex ratio has been mentioned. Workers in Africa have generally shown that variations in sex ratio follow the seasonal trends at the time of sex differentiation, which is about two years before flowering there (Sparnaaij, Rees and Chapas 1963). High sunlight intensity particularly

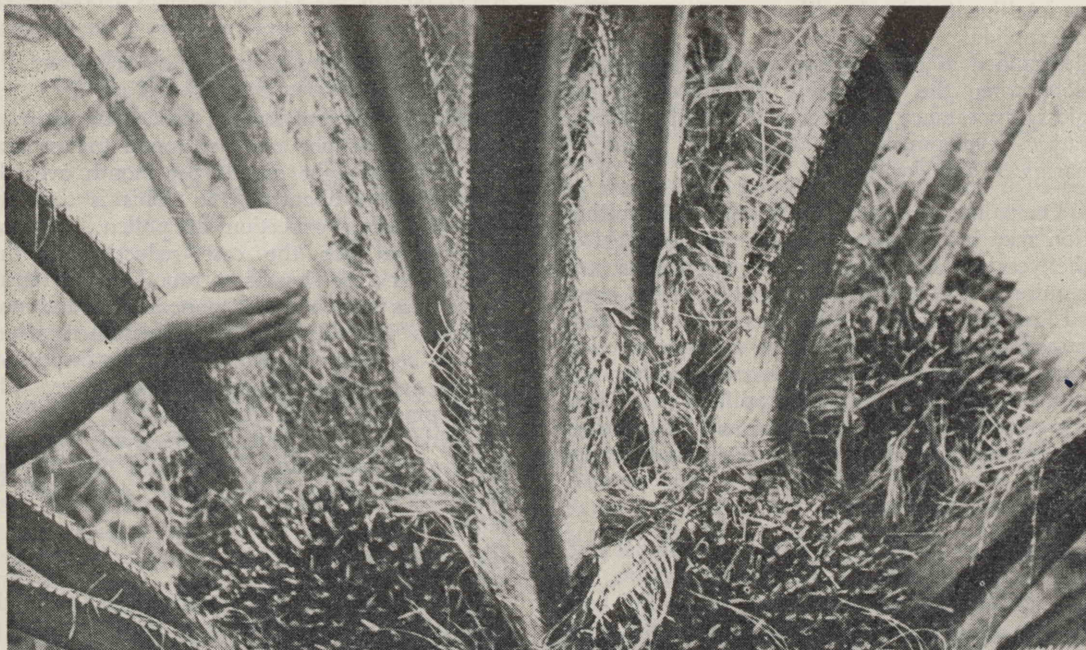

Plate VII.—Assisted pollination using a simple hand method. Such good fruit set on young palms may only be possible with assisted pollination.

Palm year in the field.	F.F.B./acre tons.	Per cent. Oil to F.F.B.	Oil/acre tons.	Kernels/acre tons.
3 (24-36 months)	0.5	14	0.07	0.02
4 (36-48 months)	3.6	16	0.6	0.16
5	6.3	17	1.1	0.28
6	8.7	18.5	1.6	0.42
7	9.2	20	1.8	0.46
8	9.7	21	2.0	0.48
9	10.0	22	2.2	0.50

appears to favour differentiation of female flowers. The effect of climate in the last 12 months before harvest on yield is also quite marked (Hemptinne and Ferwerda 1961), where drought tends to make inflorescences abort, and has an effect on pollination, fruit set and fruit development. A three-year-yield cycle is generally found in West Africa (Haines 1959), where peak yields occur when a high sex ratio in the palm coincides with optimum climatic conditions for fruit set and development.

Few studies of this type have been done in Malaya, but the climate produces a much higher sex ratio than in Africa and the limiting effect of climate is mainly in male flower production while the palm is young. Drought is a very minor factor in Malaya, on the coastal clays at least, and yield variation is generally very much less than in Africa. Whereas in Malaya 10 to 12 per cent. of the yearly crop may be in the peak month, and 6 per cent. in the lowest month, the corresponding figures in West Africa may be 15 per cent. and 3 per cent.

Fruit Ripening.

The fruit in the crown of the oil palm bunch usually ripens first, and the last fruit 8 to 18 days later, with the longest period for young palms. The oil content in the mesocarp of the fruit rises to about 52 per cent. when fully ripe, but may be only 30 per cent. in unripe fruit at the base of a bunch even when the top fruit are ripe.

After ripening, fruits tend to drop off the bunch, and any damage such as cutting or bruising will result in a rapid rise in free fatty acid (F.F.A.) content at the damaged surface, due to enzyme breakdown of the oil. Hence, the more fruits that are ripe at harvest, and the more damage a bunch is subject to in cutting and transport, the higher the F.F.A. content will be in the extracted oil. Since the price for palm oil is based on 5 per cent. F.F.A., with a premium or penalty for each 1 per cent. below or above this figure, it can be seen that a compromise between oil content of the bunch and F.F.A. of the product must be reached, as each bunch is harvested as a unit. Another compromise must be made between the value of the oil in the bunch and the cost of harvesting and transporting it. Each bunch would have its maximum oil value on a single day, but it is not possible to harvest the whole estate each day. On a weekly round, a fifth of the estate might be harvested each working day.

Once a harvesting round to give the desired quality has been worked out, a standard of minimum ripeness needs to be established for the cutters. Often, when a seven to ten day round is used, the standard may be at least as many loose fruit on the ground as the bunch weighs in pounds, for example 30 loose fruit for a 30 lb. bunch. Where the round is longer, or palms are younger the standard may be set at a smaller number of fruit. The evacuation system will also be taken into account, since more handling and a longer time in transit will mean increased F.F.A. An estate with a less efficient system may have to set their standard at a lower number of loose fruit to produce the same quality oil.

The Cutting Operation.

A chisel is normally used for harvesting young palms (*Plate* VIII), then often an axe until the bunches are out of reach from the ground (*Plate* IX), and then a curved knife on a bamboo pole (*Plate* X). A recent pruning experiment, referred to in "The Oil Palm in Malaya", has reinforced the general recommendation that at least the frond below the developing bunch should remain until the bunch is harvested. With young palms the removal of as few leaves as possible is probably desirable until the lowest bunch is about 3 ft. from the ground. This is best done with chisel harvesting. Fronds below the lowest bunch, not removed during the harvesting of mature palms, usually subtend a male flower or aborted female and can be removed by the harvesters or by a special pruning gang.

Plate VIII.—A chisel being used on a young palm, about four years old, in this case for light pruning.

The harvester usually cuts away any hindering fronds, and then cuts the ripe bunch, letting it fall to the ground. Normally he should be able to cut about 90 bunches per day in older areas or about 200 in young areas bearing well. He is usually paid a rate based on number of bunches and height of palms.

Fruit Evacuation.

This hotly debated subject was dealt with in a seminar recently (Sabah Planters' Association 1965). The estate layout, and method and equipment used, have a large influence on cost of oil production.

Most estates use teams of collectors, who carry the bunches and loose fruit in baskets to the nearest collection point where it is loaded for transport to the mill (*Plate* XI). The methods vary from a pair working together cutting and carrying fruit, to collection gangs separate from the cutters. One estate using teams of three women finds that each team can cover about 15 acres per day, or 24 in young areas. A typical arrangement might be with a harvesting path down every second interline, with an average distance of 15 to 20 chains between roads, to give a maximum fruit carry of 7 to 10 chains to the nearest road. Collection points are spaced along the roads ; for example one for each three harvesting paths.

Varying methods are used for transporting fruit from the collection point to the mill. The main ones are either a light railway network, or a complete road system employing combinations of trucks and tractors and trailers, or a mainline rail system supplied by tractors and trailers. Many other systems are found, for example on one estate where fruit is collected with a rail network and then loaded into trucks for road transport to the mill, which is some miles away on a separate estate.

It is rather unlikely that a railway would be used on a new estate now and most of those used in Malaya were established pre-war, when

Plate IX.—Axe harvesting can be started when the lowest bunch is more than about three feet from the ground.

[Photo : B. S. Gray]

Plate X.—Harvesting of a tall palm, about 35 years old, using a curved knife on a bamboo pole. Normally palms would now be cut out and the area replanted before this age.

costs were much lower. On the West Coast of Malaya, with flat land and heavy clay soils making roads difficult in wet weather, a rail system may be still economic and desirable, but the heavy initial capital cost will probably prevent their use in other areas. Quoted costs for laying a rail network were about $6,500 per mile. One estate has 52 miles of railway on 9,000 acres, another 190 miles on 21,000 acres. Good estate roads in Malaya, fully drained and surfaced with laterite, will usually cost between $700 and $2,400 per mile, depending on terrain. Fruit shells and boiler ash are widely used, although these are not usually available for initial road construction. Even if a rail system is installed, a road network is still needed for inspection purposes, transport of labour to work, and many other jobs where the railway is too slow and inflexible.

The layout of the road network is a most important factor to be considered in planning a new estate, as it can limit the efficiency of a collection system for at least 20 years. Improvements such as mechanized collection may not be used to full effect on a layout designed for a different system. Normally harvesting roads are spaced at an average distance of 15 to 25 chains apart, with main roads crossing them about every half mile to a mile depending on topography and factory location. A study was made of the variables involved in choosing the optimum harvesting road spacing (a paper presented at the seminar mentioned above). With the present hand collection system the data used gave an answer of between 17 and 27 chains, depending on whether the object was to achieve minimum costs per ton F.F.B. or maximum return on invested capital.

Prospects for mechanizing the bunch cutting operation seem slight, as quite a degree of skill and judgement is involved and an efficient job can be done if no carrying is done by the cutters. The main scope for mechanizing harvesting would appear to be in replacement of manual fruit carrying by vehicles, which can be loaded by hand as they pass down the interlines. For this to operate on a new estate, logs and stumps would have to be cleared out of every fourth interline, for example, to enable passage of a tractor and trailer. If other mechanized operations such as maintenance and fertilizer spreading are also envisaged, clearing of at least every second interline may be necessary. Where mechanized collection is intended or likely, it should be taken into account when planning the estate, as the optimum distance between roads will be increased considerably. An advantage of mechanized collection is that fruit handling can be reduced, enabling the cutting of more mature fruit without a decrease in oil quality.

NUTRITION.

The oil palm, being such a heavy yielder, will often respond very well to fertilizers, and large quantities are now being used on Malaysian oil palm estates. The palm makes particular demands on potassium, with magnesium, nitrogen and phosphorus also important among the major elements (Rosenquist 1962). Boron and some other minor elements are also important in many individual cases.

The techniques of leaf sampling and analysis, which are used as a guide to fertilizer requirements, were initially developed in Malaya (Chapman and Gray 1949) and Africa (Broeshart 1954), and have been widely applied since in most oil palm growing countries. Much of the fertilizing carried out in Malaya is based on recommendations made from leaf analyses, in conjunction with field experience, visual observations and experimental results where available. An outline of sampling and analysis techniques, critical levels used, visual symptoms of deficiencies and the requirements of the main Malayan soil types is given in " The Oil Palm in Malaya ". Most of the leaf analysis and fertilizer advisory work in Malaya has been done by Chemara, who run an advisory service for estates. Harrisons and Crosfield hope to provide a similar service in 1966.

Recommendations were noted, for individual fields, of up to 30 lb. of a fertilizer mixture per palm per year, and many areas were receiving at least 10 lb. per palm, particularly on the less fertile inland soils. Experiments mentioned in " The Oil Palm in Malaya " showed that 12 lb. of fertilizers could maintain yields economically at about nine tons F.F.B. per acre per year on granite derived inland soils.

To obtain true optimum leaf nutrient levels, other factors such as soil moisture, sunlight, drainage, pests and diseases would have to be non-limiting to growth and yield. Since this is the exception, optimum levels vary with different

Plate XI.—Counting fruit bunches, and loading them for transport to the mill.

areas, climatic conditions and soil types. The levels used in West Africa are usually lower than those used in Malaya, due mainly, no doubt, to the poorer climatic conditions (Ruer 1966). The levels used by Chemara have tended to rise in recent years, with improved management and planting material.

Levels vary with the age of the palm, and with the particular frond sampled. The standard procedure now used is to take a sample from the middle leaflets of frond number 17, taking the newest fully opened frond as number one. Frond 17 is in the second row of fronds, below frond one, and is normally about eight and a half months old. The sort of tentative optimum levels used are as follows (quoted in "The Oil Palm in Malaya") :—

Major element	N	P	K	Mg
Per cent. of dry matter	2.70-2.80	0.18-0.19	1.30-1.35	0.30-0.35

Optimum levels for boron are probably 16 to 25 parts per million of dry matter, based mainly on experience of the response of leaf symptoms to fertilizers, yield responses being ill defined. A manganese level below about 150 p.p.m. may indicate a deficiency under most conditions.

As well as the actual levels of individual nutrients, the balance between them must be carefully watched ; an example being that prolonged NPK fertilizing can bring on a gross magnesium deficiency. Antagonisms between a number of elements are also known.

Visual deficiency symptoms vary greatly in diagnostic value. Magnesium and potassium are of considerable value and fairly characteristic. The symptoms were first described and used in West Africa (Hale 1946, and Bull 1954). Magnesium deficiency usually appears as a bright yellow bronzing of the lower fronds, whereas potassium deficiency usually occurs as darker orange spotting on the fronds. Nitrogen deficiency is seen as pale green leaves, but only when the deficiency has become severe, and with a serious loss in yield. Boron deficiency (Bull and Robertson 1959) gives rise to a variety of symptoms readily seen in many areas, mainly due to brittleness of tissues and constriction of tissues in the bud. Such symptoms are hooking of leaflets tips, stunting of fronds and possibly tearing of leaflet lamina away from their midribs. These conditions are referred to as 'hook leaf', 'little leaf' and 'leaflet shatter' respectively.

Another common leaf condition is referred to as 'white stripe', and appears as a very pale yellow or white stripe down the leaflet lamina on both sides of the midrib. Indications at present are that the condition is a result of high nitrogen and low potassium levels in the palm, often where leaf nitrogen exceeds 3.0 per cent. and the N/K ratio exceeds 2.5. With severe white stripe, symptoms ascribed to boron deficiency can also occur, but this may be secondary.

With the very different soils of Papua and New Guinea, Malayan and African foliar diagnosis methods and results will need to be applied with care, and correlated with results of trials and field experience before fertilizer recommendations are made. Most of the foliar symptoms mentioned above have been seen on palms in this country, and it is expected that symptom surveys and foliar analysis will be just as valuable as in Malaya and elsewhere.

DISEASES.

Malaya has been comparatively free of certain serious oil palm diseases found in West Africa, such as Vascular Wilt and *Cercospora* leaf spot [Turner 1966 (*a*)], but several other diseases are of major or increasing importance.

Ganoderma infection, or Basal Stem Rot, has been known on old palms for many years, but only recently has the infection of young palms become widespread, particularly on the coastal clays. Turner [1966 (*a*) and (*c*)] gives a description of the disease, reviews experimental and survey work carried out, and recommends control measures.

Symptoms are similar to those of drought, namely wilting and failure of young fronds to open (*Plate* XII). This is due to destruction of water conducting tissue at the base of the palm, which may finally become almost a solid block of fungus producing typical bracket fungus sporophores on the outside. All major outbreaks have been on ex-coconut areas, and to a lesser extent ex-oil palm, with only a low incidence, usually less than 1 per cent. infection after 15 years, on areas developed from rubber or forest. An ex-coconut area on one estate seen had a field of six-year-old palms with 13 per cent. already lost, and probable infection over 50 per cent. Another area had 50 per cent. infection, measured by sporophore appearance, after 15 years, with almost 100 per cent. showing some foliar symptoms. Infection in ex-oil palm areas tends to be lower, 25 per cent. after 15 years.

The method of infection and spread of the disease has been fairly clearly established. Spores land on coconut stumps and logs which are then colonized by the fungus, in about two years for stumps, and one year for logs. An oil palm planted near the stump will become infected when its roots come into contact with it. The speed of infection and the length of time until symptoms are seen varies, probably mainly with the inoculum potential of the stump which is related to the volume of colonized tissue. A figure of 45 cu. in. has been put forward as a minimum sized piece of tissue to give infection under experimental conditions (Navaratnam 1965).

The only effective control method seems to be to remove all coconut and possibly oil palm logs and stumps before replanting. Provided that the main bole is removed small pieces of roots and other debris may not be important. In some areas coconut logs were buried for Rhinoceros beetle control, and these gave the worst infection of all. The cost of complete clearing of coconuts is much higher than normal clearing of forest or rubber, quoted as $75 to $90 per acre, against $48 and $36 to $54 respectively (B. S. Gray personal communication). At present the use of large bulldozers is recommended for clean clearing and stacking of coconut logs and boles. Poisoning with arsenite may not be necessary before felling, as good burns have been obtained with freshly felled coconuts.

Marasmius palmivorus infection of the developing bunch is one of the main causes of direct crop loss in Malaya (the other being rat damage). This disease appears to be of increasing importance on the coastal clays and peats, and is discussed by Turner (1965). The fungus is normally a saprophyte living in debris accumulating in leaf axils and other places in the crown, but when a large mass of dead material accumulates, usually in the form of unpollinated bunches, the fungus can become a parasite, with the build up in inoculum potential. White mycelium spreads from the unpollinated bunches to healthy ones, causing them to rot. The

Plate XII.—A palm showing the external symptoms of *Ganoderma* infection. Another to the right and behind has been completely killed by the fungus.

disease is most severe on young bearing palms, with the likelihood of these carrying unpollinated bunches.

The main control measures recommended are palm hygiene, involving removal of unpollinated bunches and possibly close pruning, and effective pollination, which usually means an assisted pollination programme. Normally any good bunches becoming infected must be removed, but trials to find an effective fungicide are being carried out. Antimucin at 0.12 per cent. has given good results on partially infected unripe bunches (P. D. Turner 1966, personal communication). Under normal conditions with healthy palms the disease should only arise with bad palm hygiene, but with rather weak palms on acid peat soils, the disease appears to be rampant in spite of control measures, and a fungicide programme may be necessary.

Crown Disease is the name applied to a condition which is often seen in young palms up to about three years old, and is most likely physiological in origin. It normally occurs only on vigorously growing palms ; and may be due to an excess nitrogen supply or imbalance in other nutrients. A dark wet patch appears in the middle of unopened fronds leaving an area bare of leaflets on the rachis which usually bends at this point. All fronds can be affected, and all bent over in a different direction. The condition has been likened to 'growing pains', and normally palms recover by the third year.

Blast is a serious root disease in nurseries in West Africa (Robertson 1959), and occurs during the dry season when soil moisture drops below about 10 per cent. and soil temperature rises above 29 degrees C. Light textured soils appear to be worse for blast. A *Pythium* sp. invades the root primarily, enabling *Rhizoctonia lamellifera* to invade aggressively, and cause a dry rot to spread rapidly up the cortex. The external symptoms are those of drought, the outside leaves browning and drying first. Little of this has been seen until very recently in Malaysia when large outbreaks were found in two polythene bag nurseries [Turner 1966 (*b*)]. The disease can be prevented fairly readily by shading, mulching or particularly by heavy watering, all playing some part in increasing or conserving soil moisture and lowering soil temperature.

All the above-mentioned diseases may occur in Papua and New Guinea under similar conditions, and *Ganoderma* infection particularly will need to be carefully considered if old coconut areas are to be replanted. Blast disease is almost certain to occur, with polybag nurseries and light soils, unless preventative measures (mainly heavy watering) are taken.

PESTS.

Oryctes rhinoceros, the Asiatic rhinoceros beetle, is the major insect pest of oil palms in Malaya. Young palms are vulnerable, and must be protected by application of the known control methods, which mainly involve destruction or hiding of breeding places, mainly rotting logs, stumps and other debris. Experiments carried out by Chemara have shown the advantage of a thick legume cover over bare ground, where the latter gave a tremendous build up in larvae and pupae. Some cover crop experiments of Harrisons and Crosfield have also indicated this, where bare ground, slashed grass, creeping legumes and bushy legumes in that order gave a decreasing amount of beetle damage on palms in these plots. *Flemingia congesta*, as already noted, gave particularly good protection if allowed to grow to about 5 ft., apparently restricting flight as well as breeding.

Infestation coming from village coconuts on the outside of oil palm estates is very common, and palms close to these may require special attention such as hooking out beetles, and dusting crowns with an insecticide such as B.H.C. Generally on estates, though, effective control is obtained with good cover crops combined with regular inspection of possible breeding sites and collection of larvae. Secondary infestation of damaged palms by the palm weevil, *Rhynchophorus* sp., does not seem to be as common in Malaya as in Papua and New Guinea, but appears just as destructive in the isolated cases when it does appear.

The occurrence of *Metisa plana* Wlk., and other bagworms as major pests in Malaya has served to emphasize the importance of predators and parasites of a pest species in tropical agriculture. Wood (1965) describes how large scale use of residual contact insecticides such as dieldrin and endrin have induced severe outbreaks of caterpillars on three estates in Malaya. One of these suffered a 30 per cent.

crop loss when the whole 6,000 acres was repeatedly sprayed. This estate has since ceased spraying, and pest attacks are decreasing rapidly as parasitization builds up. The use of more selective insecticides such as lead arsenate, a stomach poison, is now recommended if outbreaks are really serious, otherwise no artificial control measures at all should be used.

Rats are the main mammal pests in Malaysia, and cause considerable damage to young palms newly planted out, and later to fruit bunches. 'Rat collars', made of strong wire mesh, may be necessary if palms are planted in the field before they are 12 to 14 months old. The main problem is protection of fruit bunches, which are very attractive to rats. A regular and systematic poisoning campaign is the only really effective control measure, based on either the use of acute poisons such as zinc phosphide, or the newer warfarin based poisons which are probably the best. A variety of bait formulations are used, the requirement being that the bait is more attractive than the fruit. One apparently successful bait was made from warfarin, coconut cake, fish heads and palm oil, mixed with melted wax for setting into small blocks.

Birds, porcupines, pigs and elephants can also cause considerable damage, the last being in the habit of kneeling on young palms, and pulling them up by the roots to chew the soft tissues inside.

PROCESSING.

Small scale processing methods are almost universally regarded as undesirable in Malaysia, especially when producing oil for export. The generally quoted minimum acreage to support an efficient mill is 2,000 or preferably 3,000, with any size over 5,000 acres being regarded as close to optimum. Most of the large oil palm factories in the world today have been made by Gebr. Stork and Company of Holland (*Plate* XIII). Twitchin (1955 and 1956) discusses palm oil machinery and processing, and an outline is also given by Newton (1961). Various brochures of the Stork Company are also available.

Briefly, the process involves reception of fruit from the field, steam sterilizing to prevent further enzyme breakdown of the oil, and stripping of the fruit from the bunch. After digestion of the fruit, the oil is extracted from the mesocarp in a press, and then clarified and stored in bulk, ready for shipment. The press cake after oil has been extracted is broken up, and fibre removed in the 'depericarper'. Fibre is blown off through a 'cyclone' to the boilers, where it is used as fuel. Nuts are then dried, graded and cracked. After separation from shell pieces, the kernels are dried and bagged for shipment. The empty bunches after stripping are sometimes incinerated, the ash making a valuable fertilizer with a high potassium content. Shells can be used as extra fuel if necessary, or for surfacing estate roads.

Many new features are now being incorporated in mills being built in Malaysia by Stork and others. Steam turbines are being used to drive electric generators, individual electric motors power each item of machinery, and more automation is used, such as automatic hydraulic presses, kernel separation and fuel feed to the boilers.

Mills are usually built in stages, to correspond with rising production from areas being planted up and coming into bearing. The final capacity is calculated from expected total yields, and must be able to handle production during the peak months, usually by running about 22 hours per day. Mills will normally be operating about 300 days per year. The capacity of a mill will be between about two and three tons F.F.B. per hour for each 1,000 acres of palms. For a 5,000 acre estate, a mill of 10 to 15 tons per hour capacity would be needed, depending on the expected total yields and seasonal variability.

Storage and transport of oil.

Oil is usually stored at the factory in heated tanks of between 200 and 500 tons capacity, and then moved out in rail or road tankers to the nearest port, where heated bulking installations are available. The very good rail and road system in Malaya enables the shipping of almost all oil through either Singapore, Port Swettenham or Penang.

The case of two estates on an isolated part of the Sabah coast may be more pertinent to likely conditions in Papua and New Guinea. These estates will supply oil to a bulk installation and shipping jetty a few miles from both mills. A seven-and-a-half-ton road tanker will be used for transport since a pipeline is normally regarded as impractical over about a quarter of a mile and, as oil is best pumped at 135 degrees F., would need to be heated along its length. The estates, of about 6,000 acres each, will eventually be producing about 2,000 tons of oil per month between them, most of which will be stored at the mills. When a ship calls, usually to collect between 500 and 1,000 tons, oil will be pumped from one or both of the 500 ton tanks, through a 6 in. diameter pipe rising to a height of 30 ft. at the end of the jetty, and into the ship via a flexible hose.

COSTS.

An indication of the likely range of costs for establishing and running an efficient estate in Malaysia is given below, based on figures given by estates and research stations in Malaya and Sabah, and in "The Oil Palm in Malaya". Figures have been converted from Malaysian currency, usually rounded off, to Australian currency, and hence may not be meaningful to the full number of significant figures given. Labour cost and efficiency will influence the figures given. The base wage in Malaya is about $0.90 to $1.05 per day, and in Sabah, $1.20 to $1.35, though many jobs such as harvesting are done on a piece work basis.

ESTABLISHMENT COSTS.

(*a*) *Direct field costs* up to bearing at three years in the field, per acre.

Operation.	Cost ($A)	
Clearing and burning	39-48	Depends on forest density.
Lining and holing	3-9	Depends on soil type.
Planting	6-7.50	
Nursery costs—		
85 pregerminated seed @ 18 to 21c		
64 final seedlings @ 21 to 24c		
Total Nursery	29-33	Polybag nursery.
Fertilizers	6-30	Depends on needs and policy.
Cover crop seed and planting	4.50-7.50	
Cover crop fertilizers	0-9	Depends on needs and policy.
Weeding of covers and palm circles—		
Year 1	18-24	Depends on vigour of covers and weed species, and policy.
Year 2	12-21	
Year 3	6-18	
Roads .008 to .014 mile per acre at $1,800 per mile	14-25	Road building costs may vary widely.
Drains. A full system on coastal clays may cost $18 to $24	0-24	Many areas need no draining at all.
Pests and diseases (years 1 to 3)	3.60-18	Very variable.
Castration—		
14 to 26 months at $0.30/acre/month	3.60	Length depends on policy.
Total direct costs—very approximate	180-240	May be more if developed on ex-coconut area.

(*b*) *General estate establishment costs.*

	$A per acre.
Factory	160
Staff housing	30
Labour and general buildings	60
Vehicles and mechanical equipment	50
Total	300

RUNNING COSTS.

(*a*) *Maintenance*, bearing palms.

	$A/acre/year.
Selective Weeding, hand slashing	2.70-6.00
or Mechanical slashing (no logs)	1.80
Weeding of paths and circles—	
6 rounds hand weeding	3-5.50
or 2 rounds herbicides	1.50-2.40
Fertilizing, with 2 to 15 lb. of mixture, assumed 3c/lb.	4-27
Assisted pollination (up to eight years old) eight rounds per month at 3.5 to 7.5c/round	3.50-7.50
Pruning—	
1 round per year....	1.20-1.80
Diseases and pests—	
arbitrary figure, with no serious outbreaks	0.90-1.80
Road maintenance—	
Low cost if properly surfaced	0.90-2.40
Drain maintenance—	
normal range on coastal clays $1.20 to $1.40	0-1.40

(*b*) *Harvesting and processing.*

Harvesting. $2.10 to $4.50 per ton F.F.B., depending on height and yield of palms. Usually a minimum at about seven years old.

Processing. $7.50 to $12 per ton of oil, depending on size and efficiency of mill and extraction rate of oil to F.F.B., which is low with young palms.

$5.10 to $7.50 per ton of kernels.

(*c*) *General running costs* on an estate, including salaries, insurance, rents, repairs, labour welfare, etc., may be about $15 to $24 per acre per year.

SUMMARY.

With large areas of land possessing suitable climate and soils, and with the world market for fats and oils in a sound position, the prospects for an oil palm industry in Papua and New Guinea appear bright. High yields, of the order of two to three tons of oil per acre per year, and a relatively stable price of approximately $200 per ton mean that the oil palm is one of the most attractive and profitable tropical crops. The industry in Malaysia is expanding very rapidly at present, with a combination of favourable climate, both physical and economic, and improved management techniques and planting material. It would appear that Papua and New Guinea can benefit greatly from the knowledge and experience of oil palm cultivation gained there.

Large scale processing is needed for efficient production of high quality oil. This means that large amounts of capital are required, of the order of $2.5 million to bring a 5,000 acre estate and factory into production. Smallholder production, where fruit is sold to a central factory, should be a feasible addition to estate production.

Some of the important developments in oil palm cultivation recently include the breeding of high yielding *tenera* planting material, improvement of the germination characteristics of the seed using the 'dry heat' method, and development of superior nursery procedures, particularly using polythene bags.

The very favourable Malaysian climate tends to induce a shortage of male flowers, and hence pollen, in young palms, and this is likely in Papua and New Guinea also. The practice of assisted pollination is quite widespread, particularly on fertile soils, and under these conditions is necessary to obtain high yields from young palms. Castration, or removal of inflorescences before they set fruit, is a growing practice on very young palms. It is claimed to bring palms evenly into production, make early harvesting more efficient, and reduce disease susceptibility. The treatment probably builds a palm able to cope with the heavy bearing ensured by assisted pollination also.

Leguminous cover crops are usually grown in young areas for a variety of reasons, including weed control, effect on soil fertility, erosion prevention and pest control. The various species

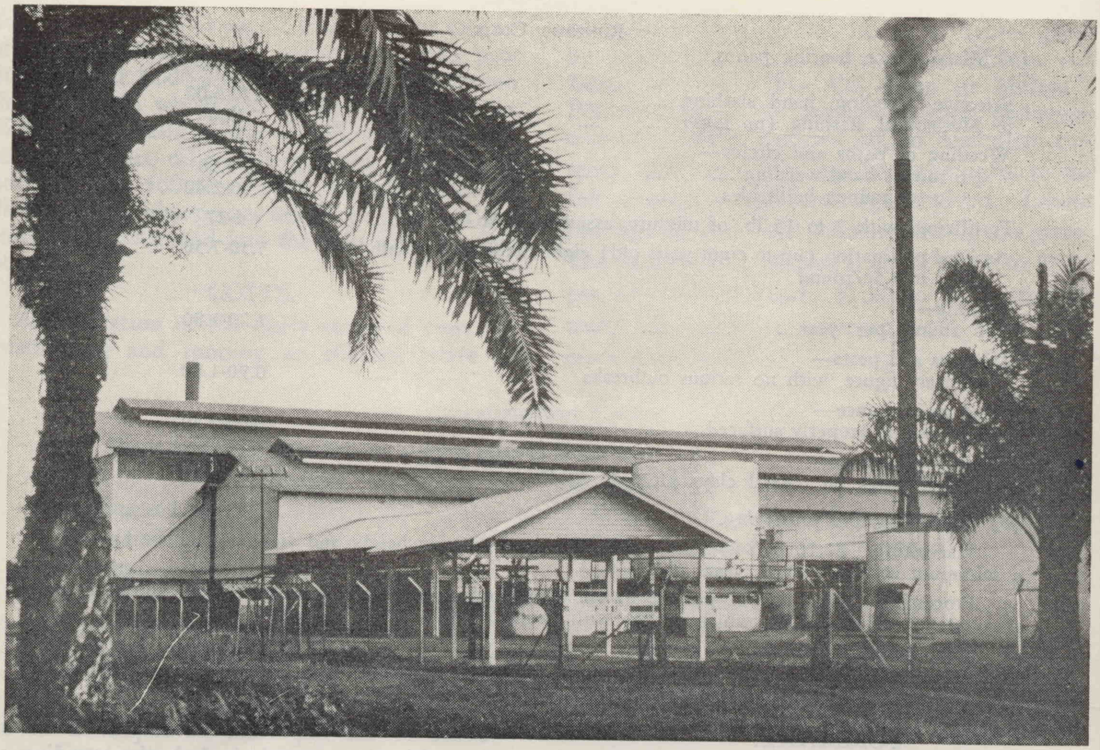

Plate XIII.—A typical oil mill. The weighbridge is in the foreground, with the horizontal sterilizers directly behind. To the right are bulk oil storage tanks.

and establishment methods are discussed. Covers are shaded out in mature areas, and upkeep then involves slashing, elimination of noxious weeds, and clean weeding of palm circles and harvesting paths by hand or herbicides.

The high yielding oil palm makes heavy fertilizer usage necessary on most soils, at least after a few years bearing. Magnesium, nitrogen, phosphorus and particularly potassium are in heavy demand, with deficiencies of a number of minor elements being found on some soils. Fertilizer recommendations are usually based on leaf analysis, in conjunction with leaf symptoms, experimental results and field experience.

The principal disease in Malaya is *Ganoderma* Basal Stem Rot, which is mainly a problem on ex-coconut and ex-oil palm areas, and the main control measure is removal of the infection sources, old coconut or oil palm stumps. *Marasmius* bunch infection, and a number of nursery diseases such as Blast are also important. The main insect pest is the Rhinoceros beetle, and control measures are based on elimination of breeding sites. Use of non-selective insecticides has led to severe caterpillar outbreaks on some estates. Rats are the main mammal pests, and are usually controlled by poisoning.

Methods of fruit harvesting, and the factors affecting choice of these, are discussed. Fruit must be harvested about every seven to ten days, and, with the very heavy fruit yields (10 tons per acre per year for example), the operation usually represents between one-third and two-thirds of the field running costs of an estate. The main scope for improvement would appear to be in elimination of manual fruit collection, and in streamlining evacuation systems.

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