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MECHANIZATION OF OIL PALM PRODUCTION IN MALAYSIA

by

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I. INTRODUCTION

Malaysia is the world's leading producer and exporter of palm oil, accounting for over half of the world's output and almost two-thirds of the world's export. The expansion of areas planted with oil palms in Malaysia during the last decade or so has been rapid and substantial. This trend appears likely to continue in the future due to the fact that Malaysia is located in the region with the best conditions in the world for growing oil palms. With these favorable conditions, together with good management techniques, a yield of up to 6.1 metric tons of palm oil per hectare is therefore possible.

Oil palm (*Elaeis guineensis* Jacq.)is an oil producing crop having an economic life of about 30 years. The palm yields fruit after three years and reaches its maximum yield at the age of 10 years. Because of its long production period, the risk and uncertainty of this industry is very high. Therefore, forecasting consumption and long term costing of palm oil is very necessary.

Much of Malaysia's oil palm industry growth has been due to the country's successful efforts at finding markets for palm oil, especially refined palm oil. However, the world market for palm oil is a very competitive one with many other edible oils and fats vying for shares of the market. Oils from annual crops such as soybeans, rape-seed, sunflower, cotton-seed and ground-nuts are important competitors. Nevertheless, the oil palm is in an advantageous position over the soybean and other oil crops grown in the temperate countries because it gives the highest yield of oil per unit area.

At the moment, palm oil and palm kernel oil are mainly used as frying and cooking oil as well as in the making of margarine and confectionery. One of the qualities of the oil is that it does not turn rancid easily. In the future, more research should be done to find more uses for the oil, and to switch people's taste from other oils to palm oil. In this manner, palm oil will surely have a greater share in the world market.

Oil palms were first planted commercially on estates in Malaysia in 1926. Since then, areas cultivated under oil palms have increased drastically: 1979, about 900,000 hectares were planted with oil palms. The rapid increase in total acreage, however, does not go hand in hand with the availability of labor force. The imbalance between total acreage and total labor have forced more estates to mechanize their production line. Insufficient workers to perform the various operations have started to cause problems, especially in the areas of greatest expansion, such as in the state of Johore. In these areas, not enough workers are available to remove all the fresh fruit bunch (f.f.b.) at optimum maturity, thus resulting in loss of fruit and a potential increase in free-fatty acid (f.f.a.) of oil which, in turn, results in poorer quality and lower prices.

The production of oil palms undergoes various field operations. Some of the main operations include land preparation, planting, drain construction and maintenance, pesticide and fertilizer application, pollination and harvesting. All these operations require many workers, especially the harvesting operation. In order to maintain a high quality of oil, the fruit should be harvested at the right time and then sent to the oil mill immediately.

In recent years, however, there has been increasing difficulty in obtaining sufficient workers to harvest palms, particularly tall palms. Currently, the oil palm industry is facing a shortage of labor particularly acute in f.f.b. harvesting and loading, since workers with strong physiques and specialized skills are required. There is a need to maximize mechanization on the oil palm estates to overcome some of the labor shortage problem. Mechanization has also been suggested as a method to improve productivity and make the task of harvesting or performing other jobs more acceptable to the workers.

Mechanization is not always the best solution to solve the existing problems. Sometimes mechanization can also create new problems. High initial investment and unsuitability of the machine to local conditions are always limiting factors. Therefore, it is very desirable to conduct feasibility studies in apparently suitable areas before any program of development is commenced. An economic analysis on each specific machine would be very helpful.

II. REVIEW OF LITERATURE

The agricultural sector continues to play a dominant role in the economy of Malaysia. It contributed about 22.2 percent of the Gross Domestic Product (GDP) and 40.6 percent of the total employment in 1980. Various kinds of development programs and policies have been and will be implemented to increase agricultural production and thus increase the per capita income of the population. A study by Galenson (1980), which is based on the subdivisions of the agricultural sector, shows that rubber, oil palms, rice and coconuts are the principal crops of Malaysia. Together they cover more than 90 percent of the cultivated area.

While discussing Malaysian exports of merchandise, Peter (1980) did mention that the following three factors were responsible for the rapid expansion of oil palm planting in Malaysia. Soil and climate provided an ideal environment for the cultivation of oil palm; land development schemes and estates provided the level of management necessary to achieve maximum yield; and the decline in the price of rubber during the 1960's provided the economic incentive to grow oil palms.

Current and up-to-date data and information is very important to make this report more effective. In this respect, the Malaysia Department of Statistics provided recent data and figures on oil palm acreage, number of labor force involved and other information. In relation to the production and price situation, the Malaysian Economics presented monthly and yearly production rates and average oil palm prices. This information shows trends which will be very helpful in predicting the future situation.

The problem of labor shortage in the oil palm industry has been studied by Chang (1980). He indicates that areas planted with oil palms have increased by 65 percent, whereas the labor force has only increased by 50 percent. This suggests that more timely operations should be considered in order to maximize profits.

Knowledge of the present status of mechanization in the oil palm industry in Malaysia is mostly based on the study conducted by Tam (1980), Wan Ishak (1980), Zakaria (1980), Wakefield (1980), Chan (1980) and Chang (1980) and also on the author's experience in this field. The present situation of the oil palm industry is divided into different parts in which each operation -- such as land preparation, planting, drainage, pesticides and fertilizer application, and harvesting -- will be discussed. Production of seedlings and processing of palm oil is beyond the scope of this report. Within the individual operation, a brief explanation of the various techniques will be presented. Toward the end of each operation, an estimation of the costs will be given. These are some of the prerequisites in order to determine which operation should really be mechanized.

The availability of manpower involved in each operation has a great influence on the level of mechanization. From the data collected from the Department of Statistics and the Malaysian Agricultural Producers'Association (M.A.P.A.), Chang(1980) found that the size of the labor associated with the oil palm industry has declined, indicating that more areas need to be mechanized.

Present methods of land clearing have been reported by Balakrishnan, and Lim (1976). They catagorized the mechanization of land clearing into three methods: conventional method, partial mechanization method and complete mechanization method. Lining and holing operations have been examined by Hartley (1967). He indicates that both of these operations are still done manually, except for suitable areas where a mechanical hole digger can be used. Planting of oil palms can be done successfully by using the polybag system, as mentioned by Hartley (1967).

Proper drainage systems are very important, especially if planting is to be done on coastal or alluvial soils. Hansen et al (1980) summarized some of the benefits of adequate drainage. Due to the tedious nature of the job, Adham (1980) reported that, presently, there are a few drainage machines -- such as excavators, back-hoes and trenchers -- which can be used for drain construction and maintenance. The layout of the drainage system should be designed properly so that it will provide greater access for future mechanization.

Due to the larger acreage of oil palms, the importance of pest control should also be emphasized. Great losses will be incurred in the oil palm industry if any disease outbreak occurs. As a preventive measure, applying the pesticides at the proper time should be practiced. Both ground and aerial equipment are now being used as reported by Chan (1980). Ground operated equipment includes the knapsack sprayer, boom sprayer (Bloomfield and Khoo, 1975) and airblast sprayer (Arulandi, 1971).

As a means to increase the rate of growth and yield, the oil palm growers are forced to apply additional food nutrients to their palms. Currently, manual methods of fertilizer application are widely practiced, but Wakefield and Nadarajan (1979) reported that fertilizer distributing equipment has some potential application in the future.

Toward the latter part of the report, emphasis was given to the harvesting operation. This is due to the fact that this operation has already been faced with labor shortages, and there is not much work being done to mechanize it. The harvesting operation includes (1) cutting fronds and fruit bunches, (2) collecting loose fruit, (3) transporting in the field (infield transportation), and (4) transporting to the mill (main-line transportation).

The cutting of fronds and fruit bunches is still being performed manually. However, the author has designed an improved version of the traditional method to reduce stress to the worker. Research done by Wakefield (1980) has provided figures and data on using a hydraulic lift (platform) for a fully-mechanized harvesting method.

Transporting the fruit from the palm to the collecting points located along the roadside is known as infield transportation. There are three methods of infield transportation, i.e., traditional method, animal powered system (Wan, 1973) and mechanized system. Some of the mechanized infield transportation machines include (1) the jackpak (Cunningham, 1969), (2) the forklift and (3) the dump-truck (Webb, 1976; Zohadie and Wan Ishak, 1982).

Main-line transportation, on the other hand, is the transporting of oil palm fruit from the various collecting points to the mill. Four different methods are currently being used. Lorries fitted with cranes for mechanically loading and transporting the fruit have been studied by Price and Kidd (1972). The second method utilizes a tractor and trailer which basically works similarly to the previous method. The other two methods are a light railway system and road network system using sterilized cages (Stimpson and UNIDO, 1974).

III. OBJECTIVE

The primary purpose of this report is to present a general review on the current status of the oil palm industry, particularly the harvesting operation and the possibility of mechanizing the operation.

Other specific objectives include the following:

a) To review and discuss the present level of mechanization done for various operations in the oil palm industry.

b) To make a comparative study on the different methods -- traditional method, partially-mechanized method and fully-mechanized method.

c) To present a summary of the total production cost per hectare of oil palms cultivation.

d) To determine the feasibility of mechanizing the various operations involved in the oil palm industry.

IV. SOIL AND CLIMATIC CONDITIONS FOR OIL PALMS

The soil and the climatic conditions of Malaysia are one of the three factors mentioned earlier which contribute to the present rapid expansion of the oil palm industry. The average daily temperature throughout Malaysia varies from 21.1°C (70°F) to 32.2°C (90°F), and the average yearly rainfall is about 2540 mm (100 inches).

In order to maximize production, oil palms should be planted on a flat or gently undulating land. Land with good drainage is also desirable. Hartley (1967) summarized the climatic features of areas which give greatest production:

a) A rainfall of 2000 mm (80 inches) or more distributed evenly throughout the year.

b) A mean maximum temperature of about 22-24°C (72-75°F).

c) Constant sunshine amounting to at least five hours per day in all months of the year and increasing to seven hours per day in some months.

From the topographical and climatic viewpoint, it is true that the Malaysian conditions satisfy almost all the requirements mentioned above.

In the past, most of the oil palms were planted on the coastal plains, which are normally flat and grow high yielding palms. However, due to the limited areas of flat and gently undulating land, more oil palms are grown on the inland soils, which are undulating to hilly and grow lower yielding palms. Due to these steeper slopes, palms are normally planted on terraces or benches. This kind of cropping pattern, naturally, results in problems with vehicular movements.

V. ACREAGE AND CROP DISTRIBUTION

The rate of agricultural development in Malaysia over the past ten years or so has been very rapid. In 1967, West Malaysia had approximately 20.8 percent of the total area or about 2,698,000 hectares under cultivation. By 1977, this had risen to 3,437,000 hectares or 26.4 percent of the total land area.

A look at the oil palm industry reveals that the total area planted with oil palms has increased drastically since 1967. In 1967, oil palms covered an area of about 153,000 hectares, which represented approximately 5.7 percent of the total cultivated area of 2,698,000 hectares in West Malaysia. In comparison, a total acreage of 712,000 hectares, or 20.7 percent of the total cultivated area, were planted with oil palms in 1977 (Table 1). The increase in the area under oil palm cultivation was mainly due to the new plantings undertaken by the various government agencies, particularly the Federal Land Development Authority (FELDA), and the continuing conversion of the rubber land to oil palms estates and small land holders because of the declining price of rubber.

At the end of 1980, the total area under oil palm cultivation amounted to slightly more than one million hectares. New plantings during that year alone were estimated at 118,000 hectares, an increase of 12.8 percent over the previous year. Total planted area in West Malaysia was 928,029 hectares or 88.6 percent of the total oil palm area. Oil palm areas in Sabah and Sarawak were estimated at 81,929 hectares (7.9 percent) and 36,750 hectares (3.5 percent) respectively.

The most important producing state is Johore (289,888 ha.), followed by Pahang (262,486 ha.) and Perak (115,231 ha.). FELDA is still the single

TABLE 1 Estimated Cultivated Area in West Malaysia ('000 Hectares)

Period	Oil Palm	Total	%
1967	153	2,698	5.7
1968	190	2,752	6.9
1969	231	2,812	8.2
1970	261	2,877	9.1
1971	294	2,922	10.1
1972	349	3,000	11.6
1973	412	3,076	13.4
1974	500	3,178	15.7
1975	569	3,278	17.4
1976	638	3,359	19.0
1977	712	3,437	20.7

Source: "Monthly Statistical Bulletin, West Malaysia," Department of Statistics, Kuala Lumpur, April 1980

largest producing unit, accounting for a share of almost 30 percent of the total planted area. The combined area under private estates extends over half a million hectares or 56 percent of the total plantings. The rest of the area is under the control of other federal or state agencies or small land holders.

Knowledge of the oil palm acreage by age group will be advantageous, especially when mechanization is being considered. The height of a palm tree is very much related to its age. As the palm gets older, the palm gets taller. The height of the palm tree has always been the main factor which determines the method of harvesting. How the height influences the methods of harvesting will be discussed later in the report. Table 2 shows the total acreage of oil palms, classified according to different age groups.

TABLE 2. Mature Acreage of Oil Palm Estates by Age Group as of December 31, 1977 West Malaysia in Hectares

Age Group						
3-5	6-10	11-15	16-20	21-25	26	Total
89,649	119,687	55,410	21,690	13,132	11,204	310,752

Source: "Department of Statistics Yearbook", Department of Statistics, Kuala Lumpur, 1977.

VI. PRODUCTION AND PRICE SITUATION

Production

Production of crude palm oil (CPO) has increased dramatically for the past eleven years. In 1970, West Malaysia produced only about 450,000 metric tons as compared to about 2.7 million metric tons in 1981. In 1982, production was estimated to have reached 3 million metric tons. Figure 1 illustrates the upward trends of CPO production from 1970 to 1981 (Malaysian Economics, 1982).

Production of processed palm oil (PPO) -- consisting of refined palm oil, palm olein, palm stearin and palm acid oil -- has also increased in line with the increase in crude palm oil output as well as the increase in the number of refining and fractionation plants in the country. The production of PPO in 1982 was 2.79 million metric tons, an increase of about 10.7 percent over the 1981 production of 2.52 million metric tons. Production of palm kernel and palm kernel oil in 1982 was expected to increase to 632,500 metric tons and 269,000 metric tons, respectively.

Price Situation

On the whole, the price of crude palm oil in the world market is more or less stable. Except for a few unexpected increases in price in 1974 and decreases in price in 1972 and 1980, the overall price of CPO increased steadily. Figure 2 shows a bar graph reflecting the trend of the CPO price situation. Since 1980, the price has been declining. The imbalance of supply and demand provided a major constraint on the pricing mechanism throughout 1980. The increase in production and ending stocks of major vegetable oils during the 1980 season for the three consecutive years landed

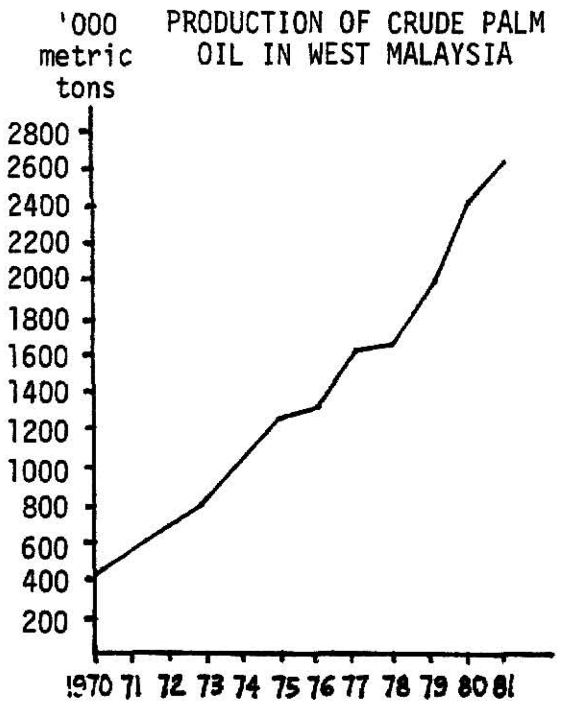


Figure 1. Production of Crude Palm Oil from 1970 to 1981

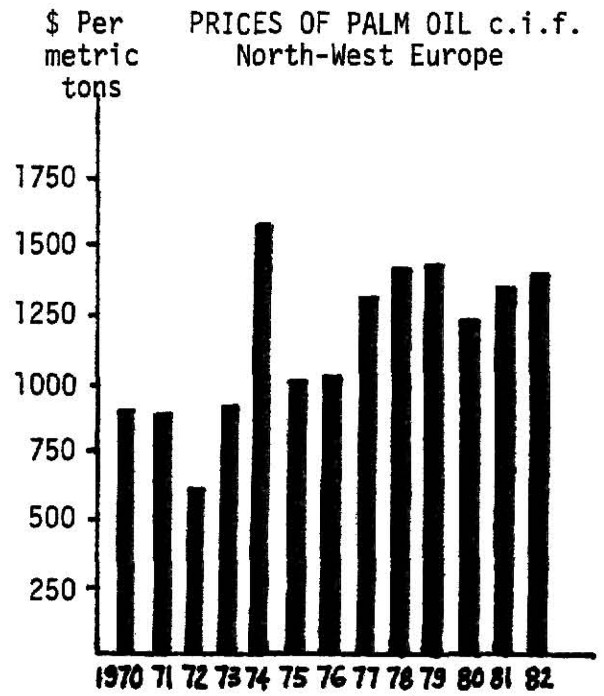


Figure 2. Prices of Palm Oil from 1970 to 1982

prices below the 1979 average of $1,425 (unless otherwise indicated, all currency amounts are in Malaysian dollars). The average price quoted in North-West Europe in 1980 for palm oil was $1,270 per metric ton, displaying a drop of 11 percent from the 1979 average.

A number of unforseen circumstances which developed during 1980 also added pressure to the already weak market sentiments. The United States grain embargo on the USSR, political disputes in Iran, Iraq and Afghanistan, and the world wide recession all triggered price declines for many oils and fats in the first half of 1980. Hopefully, when the world situation returns to normal, the crude palm oil will soon show more attractive prices.

VII. LABOR SITUATION

During the past few years, shortage of labor has become a serious problem in the oil palm industry in Malaysia. The labor force involved in this industry is declining. A study on the labor situation in the oil palm industry by Chang (1980) indicated that the labor force has only increased by 50 percent, from 47,470 workers in 1972 to 70,780 workers in 1977, whereas oil palm acreage has increased by 65 percent, from 245,539 hectares to 404,530 hectares under the same period (Table 3). Since no dramatic labor saving devices have been used in this industry during the past few years, this has resulted in a serious labor shortage.

The main reason for the reduction in labor force is due to the drift of manpower to urban areas where higher income jobs are being offered by the growing industrial enterprises around the country. Another reason is that most of the jobs associated with the oil palm industry are tedious and thus are less likely to be accepted by the workers. By utilizing more machinery and equipment, the industry can depend less on labor and the job will be more acceptable to the workers.

In addition to the estate's location, size of plantation, terrain and management policy, the availability of a labor force also has a great influence on the extent of mechanization. In areas where labor is insufficient, mechanization should be extended so that better timeliness of operation can be achieved by using the limited labor force. Therefore, efforts should be made to mechanize some of the strenuous and labor intensive operations like harvesting and transporting the fresh fruit bunches to reduce labor requirements during the peak of the harvesting season.

Table 3 shows the areas under oil palm cultivation on estates and the labor force employed in these areas for a 6-year period.

Table 3 - Oil Palm Acreage and Labor Force Employed

Year	Oil Palm Area (Ha.)+	Labor Force*
1972	245,539	47,470
1973	274,895	48,160
1974	324,618	54,380
1975	355,320	66,520
1976	377,538	71,720
1977	404,530	70,780

+ Source: " Oil Palm, Coconut and Tea Statistics Handbooks 1972 - 77," Department of Statistics, Kuala Lumpur.

* Source: " Malaysian Agricultural Producers' Association Annual Report (1973 to 1979)," M.A.P.A., Kuala Lumpur.

VIII. LAND PREPARATION

Land preparation is one of the initial operations that should be considered before any industry can be set up. Land has to be cleared from unwanted crops before planting new oil palms and constructing roads, buildings and oil mills. At present, land clearing in Malaysia probably exceeds 100,000 hectares a year. Most of the clearing has in the past been accomplished by manual methods involving a large labor force armed with chainsaws, axes and other hand tools. This is laborious and time consuming.

As the labor is becoming more scarce, more estates and plantations are depending on bulldozers and other machinery to perform the task. With the tremendous increase of land development programs, mechanization will surely be required in the future. Chang (1980), while discussing the land clearing operation, listed several advantages for mechanization:

a) Land development programs can be predicted and controlled, and work can be accelerated and adjusted to meet or suit the situation.

b) There would be much less risk involved as the job would not depend so much on environmental factors.

c) Land can be cleared and developed at a faster rate and can be in productive use sooner.

d) The final condition of land cleared mechanically is much improved since the area is free from charred logs, unburnt stumps, etc. Thus, this will allow greater access to other machinery in the later operations.

Oil palms in Malaysia can either be planted on land covered with virgin jungle or on land previously planted with rubber trees or coconut palms. These different kinds of vegetation will definitely require different methoas of land clearing. However, in this chapter more attention will be given to clearing land previously covered with jungles.

Land Clearing

As the need to mechanize the land clearing operation increased, Balakrishnan and Lim (1976) conducted a series of studies comparing three different methods of clearing jungle. The different operations were listed as follows:

a) Conventional Method:

Chainsaw felling, burning, stacking and reburning.

b) Partial Mechanization:

Chainsaw felling, burning, mechanical stacking (using bulldozer) and reburning.

Areas inaccessible to machinery were handled conventionally.

c) Complete Mechanization:

Jungle is mechanically felled by bulldozers and timber put in windrows and burned.

Areas inaccessible to mechinery were handled conventionally.

It should be noted that three methods already mentioned only cover the land clearing operations. In the overall land preparation process, lining, holing and sowing of cover crop should be included.

In order to get a better understanding of the various land clearing operations, a brief discussion will be devoted to each of these operations.

Underbrushing

This is done to make access to the area easy so that other operations which follow can be done without a lot of obstacles. At present, the work is done with cutlasses, axes and chainsaws. Depending on the thickness of the undergrowth, between 15-35 man-days per hectare, are normally required to perform the job.

Felling

Costs of clearing will be considerably reduced if directional felling is practiced. Trees are felled toward the north-south direction or along the contour. The recommended time for felling is before the dry season. In Malaysia, it is normally done between the months of November and February. Felled materials are then left to dry for two to three months before burning. Traditionally, felling was done manually using axes or hand saws. Nowadays, chainsaws are normally used instead.

Burning

Burning can be quite easy if it is done during hot and dry weather. A good burn is important so that all the felled material and other herbaceous undergrowth is completely burned. As a means to reduce the fire hazard to neighboring areas, a 20 m to 40 m cleared firebelt must be established before burning is commenced.

Mechanical Stacking

Under the partial mechanization method, unburnt logs and stumps are stacked together along windrows. This task is usually done with the aid of a 200 hp bulldozer. For the complete mechanization method of land clearing, stacking is done immediately after felling. The main burning starts only after the timber is stacked.

In conjunction with the methods of land clearing already mentioned, Balakrishnan and Lim (1976) also provide the average costs of the three different techniques (Table 4).

Table 4 - Average Costs for Techniques A, B and C ($/ha.)

Activities	Techniques		
	A	B	C
Underbrushing + felling	186.52	186.52	
Burning	12.73	12.73	
Pruning	153.36	153.36	
Timber removal along harvesters' Path		34.22	
Timber removal around planting points		29.50	
Mechanical felling			299.00
Mechanical stacking, burning and reburning			271.82
Total ($)	352.61	416.33	570.82

Source: Balakrishnan, V. and Lim, C.L. "Jungle clearing by FELDA for planting oil palm,". Proceeding of Malaysia International Oil Palm Conference, Kuala Lumpur, 1976.

Lining

The method of lining usually depends on the density of palms to be planted. In Malaysia, it has been found that the most suitable density for oil palms is as follows:

Coastal soils	150 palms/ha.
Good inland soils	158 palms/ha.
Poor inland soils	165 palms/ha.

Other determining factors include the planting pattern and the land topography. The common pattern is the triangular pattern in which the spacing is 9 m (30ft) and the rows will be 7.9 m (26ft) apart.

Holing

Holing is a method of establishing the planting hole. It can either be dug several weeks before planting or immediately prior to planting, depending on the soil type. It has been suggested that on heavy coastal clay soils, holing be done immediately before planting so that the hole does not become filled with water. The hole should be dug according to the prescribed sizes. A hole with dimensions of 0.5 m x 0.5 m x 0.4 m is very suitable for most soils. However, for peat soils, a hole 0.5 m x 0.5 m x 0.4 m should be dug inside a bigger hole 1.0 m x 1.0 m x 0.3 m. This practice will prevent the palms from uprooting due to the shrinking property of peat soils. It has been reported by Hartley (1967) that both lining and holing operations require about 6.82 man-days per hectare.

IX. PLANTING IN THE FIELD

This operation involves the moving of the seedling from the nurseries to the field and is also known as transplanting. The most common planting technique is the polybag system. Seedlings are first planted in a polybag and, after 12-14 months, are ready to be transplanted. Another method of planting which has been practiced to a lesser extent is the field nursery system. Planting of oil palms usually starts whenever the soil moisture content is sufficient for root growth after it has been transplanted. Therefore, the most suitable time for planting is in the early part of the rainy season. Always try to avoid planting in dry season.

At present, oil palms in Malaysia are still being planted manually. Polybags of oil palm seedlings are first transported to the field by tractor-trailers and then carried to the respective planting points manually. Since the planting is done only once in 20-30 years, there is less need to mechanize this operation unless there is a serious labor shortage. For the planting costs, Hartley (1967) estimated that to plant a hectare of oil palms from polybags requires about 16.56 man-days.

X. DRAIN CONSTRUCTION AND MAINTENANCE

The majority of the oil palms in Malaysia are planted on flat coastal or alluvial clay soils since these areas are the highest yielding areas. Unless a proper drainage system is constructed, the palm vigour and yields can be affected. These plantations are flat, sometimes below high tide level, and the clay soil may be only slightly permeable. Drainage is considered the best solution for reclaiming these waterlogged soils. Also, adequate drainage provides other benefits. As Hansen et al.(1980) indicated, adequate drainage (1) improves soil structure and increases and perpetuates the productivity of soils, (2) helps in soil ventilation, (3) decreases soil erosion and gullying by increasing water infiltration into soils, (4) leaches excess salts from soil, and (5) assures higher soil temperatures.

Mechanization of drainage excavation and cleaning has been practiced to some extent on large oil palm plantations. At present, most of the drains are dug with mechanical equipment. For instance, drag line excavators have been widely used to dig and maintain large main and outlet drains (usually 2.5 to 3.0 meters deep and 3.5 to 5.0 meters wide), and inter-field or collection drains (1.2 to 1.5 meters deep). However, the major drainage network, composed of 0.75 to 0.90 meter deep subsidiary or field drains, has been cut and maintained by hand (although the use of trenching equipment has been gaining popularity in recent years).

With diminishing labor availability and increasing labor costs, mechanization of the drain construction and maintenance would be very appropriate.

Selection of Drainage Equipment

Due to the high initial investment and many varieties of drainage equipment, careful consideration is necessary before making any final decision. The following points listed by Adham (1980) should be considered:

i) Suitability of the specific equipment where drainage operations are to be done.

ii) Capital and operational costs, and estimated useful life.

iii) Availability of spare parts and a repair shop.

It is important that the power and other design features of the equipment chosen are adequate and suitable for the operations. Choosing the right size of equipment not only protects it from undesirable damage but also reduces the operating costs.

Capital and other cost factors naturally must be taken into account when evaluating equipment. Most drainage equipment is very expensive and thus it should be utilized at its maximum capacity. The availability of reasonably priced spare parts and repair personnel must also be taken into account before selecting the drainage equipment. These spare parts and services are essential in order to minimize the duration of breakdowns. Long inoperational time will reduce the productivity of the equipment.

Excavator

Excavators have been used in oil palm plantations for many years and, with their improved design, they are now suitable to be used under local conditions. In the past, most excavators were fitted with a drag line. Recently, more models have been fitted with trenchers which are more versatile, more efficient and capable of producing greater output. Excavators are either fitted with caterpillar tracks or low pressure tires, depending on the soil conditions. Because of their high operating costs, excavators are normally used in digging main or outlet and collection drains. At present, the operating costs, excluding the cost due to depreciation of an excavator, usually fall between $25 to $30 per hour.

Back-hoe

The back-hoe, which is basically a rear trencher fitted on a tractor, is widely used for digging and cleaning collection and subsidiary drains. These machines are relatively easy to handle and cheaper to operate when compared to the excavator. With an experienced operator, these back-hoes are capable of digging between 20 to 25 meters of collection drains or 50 to 60 meters of subsidiary drains per hour. Excluding the depreciation costs, the operating costs range between $10 to $15 per hour.

Rotary Ditcher

Double-wheeled rotary ditchers have been evaluated and are considered the most promising choice of equipment for digging and maintaining small subsidiary drains. These ditchers are fitted to the tractor using the three-point linkage. However, the tractors on which double-wheeled rotary ditchers are mounted must be fitted with a special speed reduction gear in order to reduce the maximum operating speeds to 0.30 miles per hour. The ditcher is operated by means of the power take-off at 540 r.p.m.

Due to the potential of using the rotary ditcher, a study on its costs was conducted by Harrisons & Crosfield Agency (1980). A Dondi model of a rotary ditcher was mounted to either the John Deere (Model 2140) or Massey Ferguson (MF 185) tractors (fitted with reduction gears and extra wheels to provide better floatation and traction). Details of the ditcher and tractor costs are shown in Table 5.

Table 5. Cost Comparison Between Rotary Ditcher Mounted to Massey Ferguson (MF 185) and John Deere (JD 2140) Tractor.

i)	Dondi Double-wheeled ditcher		18,000
	Standard MF 185 tractor with accessories	33,800	
	Reduction Gears	2,000	
	Extra rear wheels & spacers	5,200	
			41,000
			59,000
ii)	Dondi Double-wheeled ditcher		18,000
	John Deere Model 2140 with accessories (plus creeper gear)	41,785	
	Extra rear wheels and spacers	4,680	
			46,465
			64,465

From the study it was found that the Dondi doubled-wheeled ditcher is capable of digging about 75 meters subsidiary drains in heavy clay soils in an hour. This shows that the operating costs vary between $5 to $6 per hour. Comparing with manual method, digging the same length of drain would cost about $36.00 per hour. The considerably lower operating costs together with better quality of job done by the ditcher will gradually replace the manual method.

Layout of Drainage System

The drainage systems on coastal estates can hinder mechanization if they are poorly planned. Wakefield (1980) found that a more suitable system would be to place the collection road at an equal distance from each drain (see Figure 3). With this system, a vehicle can service both sides of a central road, thus extending a vehicle's "run."

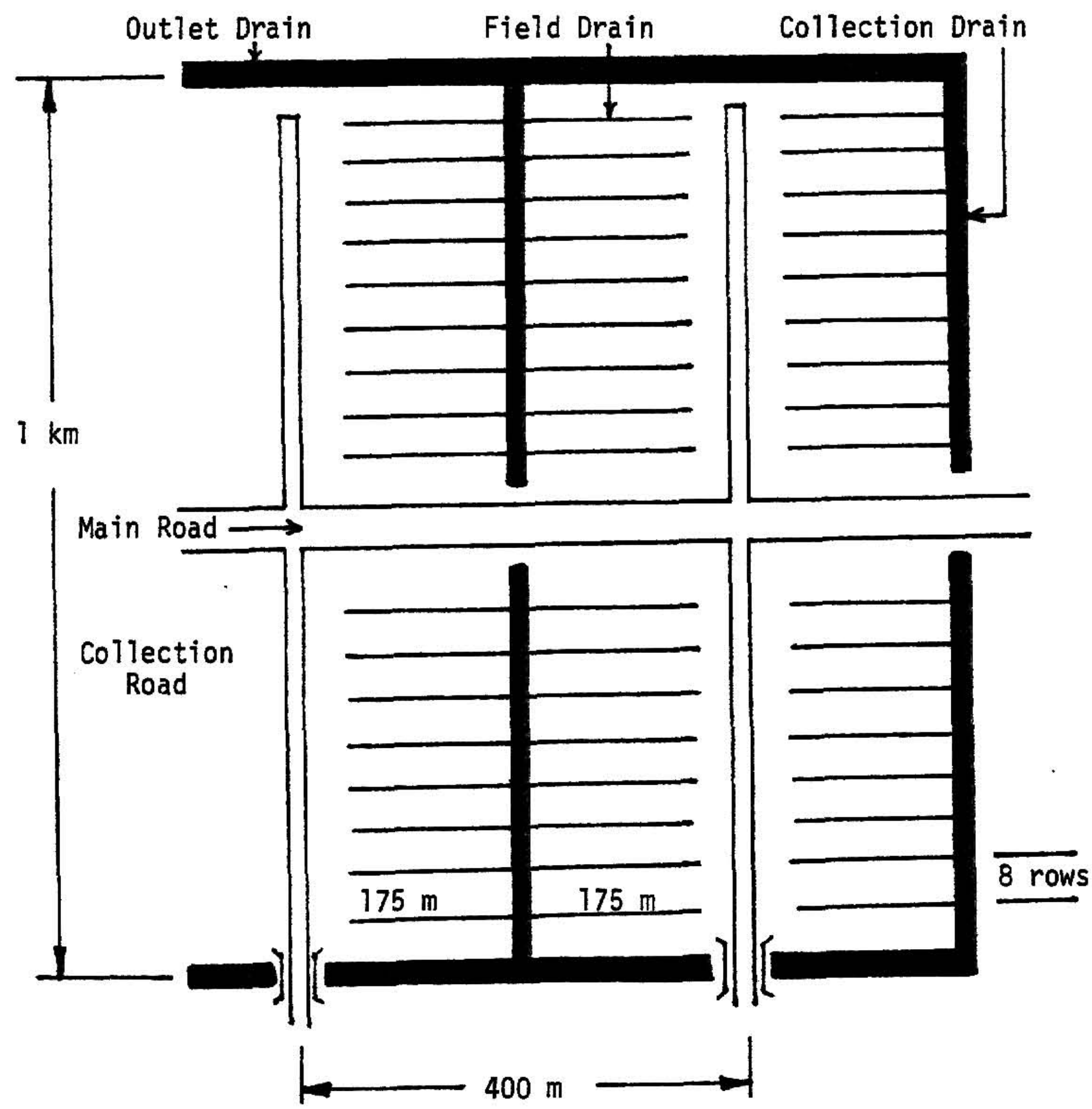


Figure 3. A diagram showing a suitable layout of road and drains for a mechanized system.

The field drains (the smallest unit of drainage in a field) also need to be planned. The greater the distance between drains, the more suitable is the system for mechanization. The best design for a field drain is to construct it after every four or eight or sixteen palm rows. This design ensures that each palm is only inspected once, and thus avoids any unproductive travel (Figure 4).

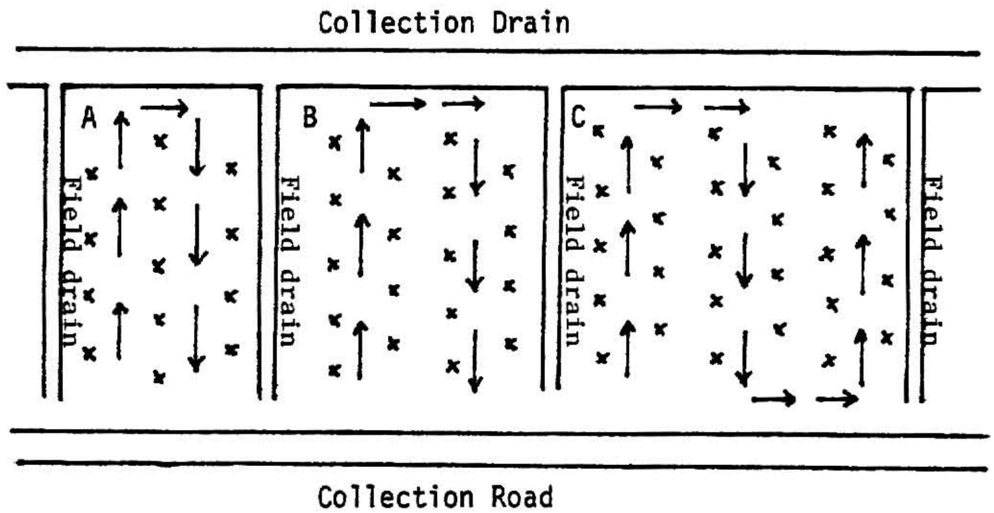


Figure 4. A design for placing the field drains.

Figure 4A shows that a design of three palm rows between field drains results in the center row being inspected twice, thus reducing productivity. Figure 4C also shows that the last two rows will be inspected twice due to the unproductive returning travel. The design having four palm rows between field drains, as shown in Figure 4B, is more suitable. In this manner the machine will only inspect each row once and then travel to the next block.

XI. FERTILIZER AND PESTICIDE APPLICATION

Fertilizers and pesticides constitute a major portion of the production cost in oil palm cultivation. For maximum effect, proper timing and correct rate of the chemical are necessary. Estates are by far the largest users of fertilizer. And, of these, oil palm cultivation takes up the greatest portion -- about 45 percent of the fertilizer used in West Malaysia is absorbed by this crop. In respect to pesticides, herbicides are used on a much larger scale than others. However, during outbreaks of pest and disease, immediate application of insecticides and fungicides is necessary to control the pest population before it reaches the economic injury level.

A large proportion of oil palm plantings are organized and managed on estates varying in size from a few hundred to several thousand hectares. The scale of operation would favor some degree of mechanization in fertilizer and pesticide applications. However, there are a few technical and management constraints which limit the use of machinery and equipment for such field operations. These constraints will be discussed below.

Mechanization with ground operated equipment is obviously not applicable to all areas because some of the crop is planted on uneven terrain. A study by Bloomfield and Khoo (1975) showed that only about 10 percent of the total cultivated land in Malaysia is accessible by ground operated equipment. Therefore, mechanized application of fertilizers and pesticides is more adapted to the flat coastal plains. Even in these areas there are some limitations. On most flat coastal plains, a good drainage system is a must. The presence of these drains will thus affect the movement of this equipment. Further, the predominant marine clay soils in the coastal plains are of low load bearing capability and soil compaction is likely to be a problem.

The use of ground operated equipment can be extended if proper planning was done prior to land preparation. Road and drainage systems must be planned and aligned not only to cater for the terrains but also to facilitate movement of equipment for various field operations. Where terraces have to be constructed, they need to be sufficiently wide and stable to enable movement of heavy machinery.

Another method of fertilizer and pesticide application is the aerial application method. This method of application is gaining popularity and acceptance for various reasons. Not only can it overcome most of the problems encountered with ground operated equipment but also, with proper planning and organization, the jobs can be completed in a shorter time. However, the major constraint to this method of application is its high operating cost.

Ground Operated Equipment

Pesticide Application

In many areas, application of pesticides is still being done with the use of conventional knapsack sprayers. This manual method of application is normally carried out to control pests and disease in the nursery and to eradicate weeds in the nursery as well as in the field. A team consisting of one spray operator plus a water carrier is required to do the job at an estimated output of 4 ha.per day (Chan, 1980).

In areas where a tractor mounted with spray tank can be used, application of herbicides using boom sprayers is more feasible. The PTO driven pump could be either of the piston, diaphragm, or roller type, depending on the operating pressure, required output, and the herbicide formulations used. Calibration is required before operating this sprayer outfit. The desired swath width and the rate of delivery would have to match with the tank capacity, tractor speed, operating pressure, choice of nozzles, etc. With this boom sprayer, an output up to 20 hectares per day can be accomplished (Bloomfield and Khoo, 1975).

To apply insecticides and fungicides, especially to tall palms, a tractor mounted low volume airblast sprayer may be used. The airblast sprayer is usually powered by the tractor's PTO. The rotating fan produces a high velocity air stream into which the insecticide or fungicide solution is injected (Figure 5). Delivery height of the airblast sprayer can exceed 18 meters. Arulandi (1971) reported that the "conomist" airblast has an output rate of about 8.3 ha. per day. The total cost per hectare was slightly higher than the hand operated knapsack sprayer. However, because of the higher rate of output and better reach (to the tops of tall palms),

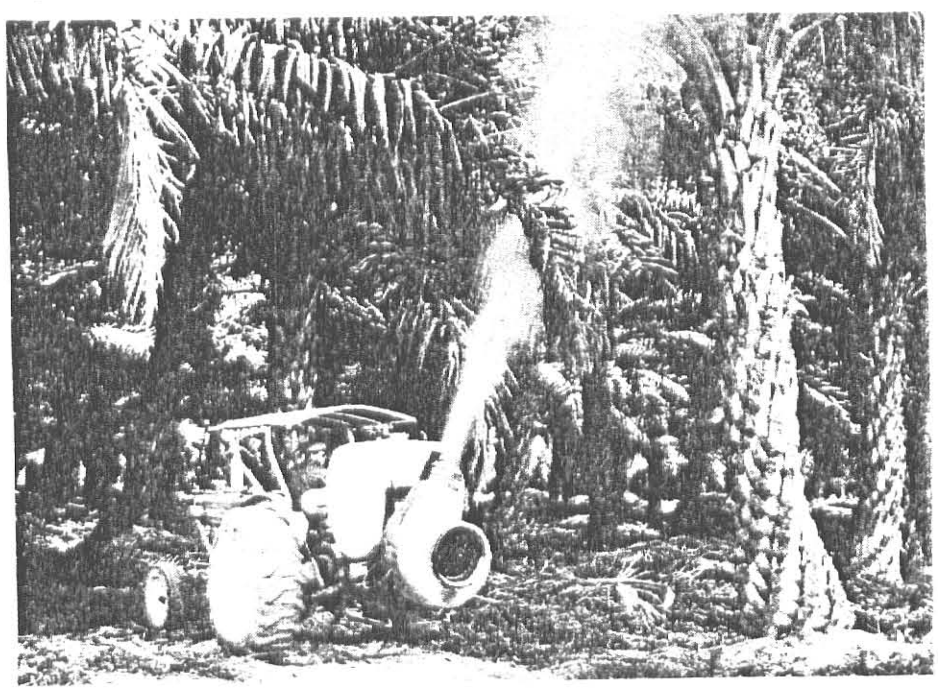


Figure 5. Applying pesticides by means of airblast sprayer.

the airblast sprayer remains an attractive piece of equipment for use in pesticide application.

Proper operation is necessary when using airblast sprayers in order to achieve a high degree of success. This includes (1) proper air volume and air speed, (2) proper ground speed, and (3) proper arrangement of nozzles. Proper air volume and air speed is related to the engineering of the machine purchased. Proper ground speed is relative to the size and capacity of the machine purchased and the size of tree sprayed. Finally, proper arrangement of nozzles refers to size and character of nozzle discs and whirl plates.

Fertilizer Application

At present, most plantations still employ the manual method of applying nutrient supplement to the palm. If fertilizer distributing equipment is used, most of it is of the broadcasting type. Recently, work has been carried out to extend the spreading and placement of fertilizer in between the palm rows using the band application technique.

In plantations where fertilizer distributing equipment is used, Wakefield and Nadarajan (1979) estimated that the Vicon model PS 600 was able to fertilize about 32 hectares per day. Further study should be done using other potential fertilizer distributing machines in order to determine the most suitable machine.

Aerial Operated Equipment

Application of fertilizer and pesticide through aerial means has so far been undertaken by fixed wing aircraft and helicopters. Even though the cost of aerial application is considerably higher compared to manual or other ground operated equipment, due to certain reasons aerial method of application seems to be more attractive to the oil palm growers. Some of the reasons include (1) the excellent timeliness and speed at which the work is accomplished despite difficult terrains, (2) uniformity of fertilizer and pesticide distributions, (3) reduced pilferage of materials, and (4) less labor and supervisory requirements. Besides the benifits mentioned above, aerial application is also considered the only method to be used in situations of serious pest and disease outbreaks over a large area of difficult terrain (Chan, 1980).

Pesticide Application

Aerial application of pesticides with fixed boom or ultra-low volume (ULV) equipment attached to the aircraft has become an accepted practice in Malaysia (Figure 6). Optimum timing is always necessary when applying pesticide by aerial means. It must be applied at the most susceptible stage of pest or disease development, at a relative humidity of 90 to 95 percent to minimize droplet evaporation and during calm days to reduce the drift problem. Another way drift reduction could be accomplished is by adding adjuvants like thickeners or invert emulsions.

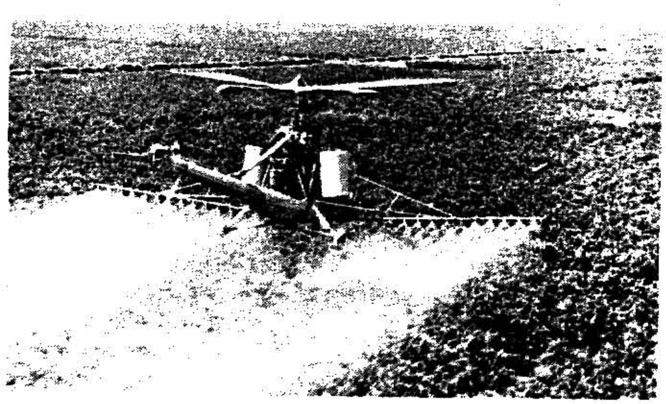


Figure 6. Using helicopter to apply pesticides.

There is a wide variation in the amount of spray coverage and the cost of application. Chan (1980) estimated that by using fixed wing aircraft, as much as 400 to 500 hectares can be sprayed per day at a cost of about $10.00 per hectare if the area sprayed exceeds 400 hectares.

Fertilizer Application

Aerial application of fertilizers is increasingly being used on matured oil palms in Malaysia. Initially, there was a fear of uneven distribution of fertilizers which might result in scorching of the growing spears. However, when Rajaratham and Chan (1977) proved that distribution of granulated fertilizers is quite uniform and scorching of the spears would not be a problem, oil palm growers started to use aerial application. As for the cost of application, Chan (1980) estimated that the cost is about the same as applying pesticide, i.e. about $10.00 per hectare.

XII. ASSISTED POLLINATION

Assisted pollination is a method practiced to produce a larger fruit bunch by introducing pollen from selected male inflorescence onto the flowers artificially. Besides producing a larger fruit bunch, the purpose of assisted pollination is also to produce bigger fruits and to reduce the number of rotten bunches.

Pollination is carried out by lightly dusting the opened flowers of a female inflorescence with the pollen or with a mixture of pollen and talc. Various methods of dusting the pollen have been tried. The most common is the use of a cigarette tin with a perforated lid or a glass flask with rubber bulb attachment or a plastic bottle for short palms. For tall palms, a pressure bulb and flask connected with a long aluminium tube, known as lance puffer, is used.

Another method which has been used widely in date growing areas is the "blow pollinator" (Alexander, 1952). The author feels that this method has a potential application for oil palm plantations due to the same properties of both trees. The "blow pollinator" consists of a small peanut butter jar, about 20 feet of copper tubing of 1/8-inch inside diameter, 6 inches of copper tubing of 1/2-inch inside diameter, four feet of 1/2-inch rubber tubing, and about 25 feet of 1-inch aluminium tubing and tape.

The top of the jar is perforated with two holes; one to take the 1/8-inch copper tubing and another one to take the 1/2-inch copper tubing. The 1/2-inch tubing was carefully bent so that one end of it would reach to the bottom of the jar and the other end passed through the hole made for it and extended at right angles to the jar. The tubing is soldered into place on the jar top. The 1/8-inch copper tubing is inserted into the hole provided for it and secured in place with solder. It is necessary that the two connections around the tubes be airtight and that the top fits tightly on the jar. The 1/8-inch tubing ends just inside the jar top. A sketch of the blower is shown in Figure 7.

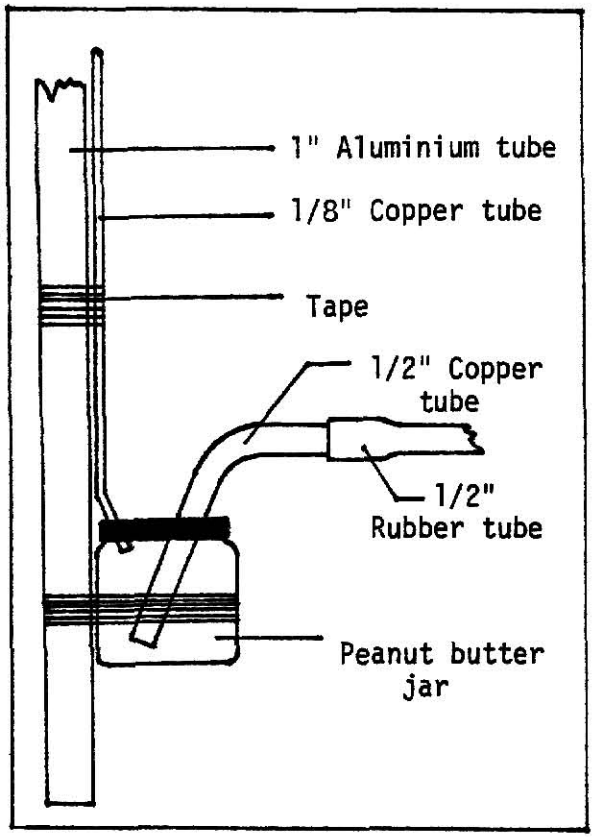


Figure 7. A sketch of a "blow pollinator".

The aluminium tube serves merely as a carrier for the 1/8-inch copper tubing, which is taped to it at intervals as necessary. The rubber is slipped over the outside end of the 1/2-inch copper tube. When the pollen is put into the jar, the lid tightened down and the rubber tube blown into, a fog of pollen comes out of the end of the 1/8-inch tube.

Assisted pollination should be done immediately after castration and continues until the palm is 8 years old. Usually this operation is performed at the rate of 6 to 8 rounds per month by women or children. A worker can normally pollinate about 30 palms per day or about a hectare per day. This means that the cost of pollinating a hectare is about $5 per round.

XIII. HARVESTING OPERATION

Until recently, with the plentiful labor supply and the relatively small acreage of tall palms being harvested, there was little need to seek improvements to the traditional methods of harvesting palms.

In recent years, however, there has been increasing difficulty in obtaining sufficient workers to harvest palms, particularly tall palms. Because of this labor problem, mechanization has been suggested as a method to improve productivity and make the task of harvesting easier and more acceptable to workers. However, mechanizing the harvesting operation does not solve the problems altogether. There are several factors which affect the acceptance of mechanized equipment. The main factors limiting acceptance are high capital and operating costs; additionally, the unsuitability of this equipment under certain conditions is occasionally a factor.

It is generally accepted that the harvesting operation has a major influence on oil quality and on oil yield. In relation to this, Wakefield (1980) has outlined several objectives which should be kept in mind when considering methods of mechanizing the harvesting operation.

i) accurate identification of ripe bunches.

ii) quick and physically easy way of cutting fronds and bunches.

iii) minimum bruising of bunches.

iv) minimum scatter and loss of loose fruit.

v) quick and easy way of collecting loose fruit and bunches.

In the following sections, different methods of harvesting will be discussed in more detail. More emphasis will be given to the economics of the individual methods as this is considered to be the most important criterion in determining the feasibility of different harvesting methods.

Cutting Fronds and Bunches

Traditional (Manual) Method

Now and in the past, two harvesting implements have been used in the oil palm industry. The first implement is a sharp chisel attached to the end of a 0.7 to 1.0 meter wooden or metal handle. Suitable chisel blades are about 6.5 cm.to 8.0 cm. wide and 0.5 meter long (Figure 8). Chisels

Figure 8. A chisel used to cut the fruit bunch of a young palm.

are often used for the first three years of harvesting or when the height of the oil palm is less then three meters. Figure 9 illustrates the method in which a chisel is being utilized.

Figure 9. Cutting the fruit bunch using a sharp chisel.

The second harvesting implement is a long curved knife, commonly called a sickle, which is attached to the end of a bamboo pole (Figure 10). This equipment is used when the palm is too high to be reached by the chisel. The pole for the hooked knife is gradually increased in length, and palms of 10 meters in height can be harvested with it. To use this hooked knife, the blade is first hooked around the peduncle and a strong downward pull is applied as shown in Figure 11.

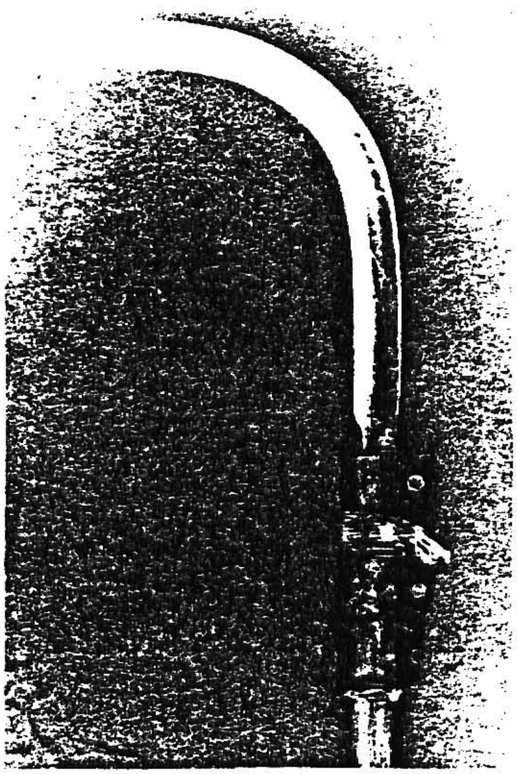


Figure 10. A curved knife used to cut the fruit bunch of tall palms.

Figure 11. A man demonstrating the use of curved knife attached to a long pole for cutting the fruit bunch on a tall palm.

Operating Cost of Manual Harvesting Method. The time needed to cut the fruit bunch and to carry the fruit bunch to the road depends on the age and the height of the palms. As the palm gets older and taller, the time spent to complete the harvesting operation increases. A study by Sanker (1966) gave some information on the time spent on the different harvesting operations (see Table 6).

Table 6 - Manual Harvesting Time Spent On Different Operations (Per Bunch)

Operation	Young	Older	Tall
Cutting time (min)	0.65	1.8	2.6
Carrying to road (min)	1.95	3.4	5.5

Source: Sanker, N.S. (1966) Fruit Collection & Evacuation by Road.

Other assumptions that have to be made to calculate the operating costs include:

i) The total number of fruit bunches harvested for a high yielding area is about 42 bunches/ha.

ii) The cost of labor is about $2.00 per hour.

iii) The harvesting interval, which is the number of days in between each harvesting operation, is 7 days.

Therefore, the number of harvesting rounds per year

$$= \frac{350 \text{ working days/year}}{7 \text{ days/round}} = 50 \text{ rounds/year}$$

iv) The calculation is based on the harvesting time needed for a tall palm.

Calculating the Costs Per Hectare Per Year.

A. Operating Costs.

i) Cutting time per ha. per year

= 42 bunches/ha. round x 2.6 min/bunch x 50 rounds/year

= 5460 min/ha.-yr.

= 91.0 hours.

ii) Cost of labor @ \$2.00/hr = 91.0 hrs x \$2.00

= \$182.00 per ha. per yr.

B. Fixed Costs.

Assumptions:

i) Estimated cost of harvesting tool = \$30.00

ii) Estimated life of harvesting tool = 1 year.

iii) Interest rate is about 7.0 percent.

Using capital recovery factor (CRF) to calculate depreciation and interest:

$$CRF = \frac{i(1 + i)^n}{(1 + i)^n - 1}$$

$$= \frac{.07(1 + .07)^1}{(1 + .07)^1 - 1}$$

$$= 1.07$$

Therefore, fixed costs on harvesting tool per year

= CRF x Capital

= 1.07 x \$30.00

= \$32.10

C. Total Costs Per Hectare Per Year.

= Operating Costs + Fixed Costs

= \$182.00 + \$32.10 = \$214.10

Improved Method

Reviewing the development of mechanization realistically reveals that many countries have undergone a revolution in agricultural machinery production and mechanization. The changes involved in the revolution, have been primarily modifications rather than major design changes. In this respect, the author has designed an improved version of the traditional harvesting implement (see Appendix 1). With the improved harvesting implement, the force required to cut the fruit bunch can be reduced up to 63 percent. The time needed to do the cutting can also be reduced.

Calculating the Total Costs Per Hectare Per Year.

A. Operating Costs.

Assumptions:

i) Cutting time is reduced by 20 percent from traditional method.

Therefore, cutting time per bunch for improved method

= 0.8 x 2.6 min/bunch

= 2.08 min/bunch.

Cutting time per ha. per year

= 42 bunches/ha. round x 2.08 min/bunch x 50 rounds/yr.

= 4368 min.

= 72.8 hours.

ii) Cost of labor per ha. per year @ $2.00/hr.

= 72.8 hrs x $2.00

= $145.60

B. Fixed Costs.

Assumptions:

i) Estimated cost = $50.00

ii) Estimated life = 1 year

iii) Interest rate = 7.0 percent

iv) Capital recovery factor (CRF) = 1.07

Fixed cost on harvesting tool per year

= CRF x Capital

= 1.07 x $50.00

= $53.50

C. Total costs per hectare per year

= Operation Costs + Fixed Costs

= $145.60 + $53.50

= $199.10

Advanced or Fully-Mechanized Harvesting Methods

The machine involved in this fully-mechanized method is equipped with hydraulic lift (Figure 12). During the harvesting operation, the machine travels in between two rows of palms and makes a stop when a ripe fruit bunch is seen. This machine is located in such a way that three palms can be harvested at each stop. The term used for this stop is "harvesting stop." "Harvesting stop" is made up of the following operations:

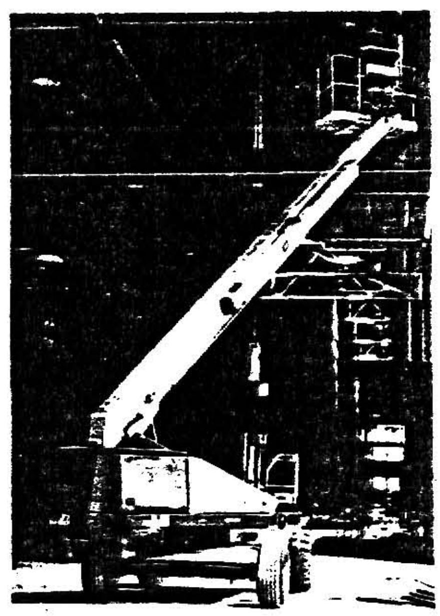


Figure 12. A hydraulic lift used in mechanized harvesting method.

i) Positioning the harvesting tool.

ii) Severing the required number of fronds to get to the bunch.

iii) Severing the ripe bunch stalk.

iv) Repositioning the harvesting tool in the travelling position.

v) Collecting the bunch and loose fruit, and placing them in in-field transport container.

One of the main time elements of the harvesting operation is the duration of each "harvesting stop." This is dependent on the yield range and the length of time spent at each stop. The other factor which needs to be examined is the "travelling time." "Travelling time" is the time required to move the machine from each "harvesting stop." A detailed operation of this fully-mechanized harvesting method was discussed by Wakefield (1980). From his study, it was found that in order to minimize the operating costs, the machine would need to travel at three miles per hour or more, and the stop time would need to be held to about two minutes per "harvesting stop."

A feasibility study of the machine was also carried out. A cost analysis was done to determine the cost per minute (see Appendix 2).

Calculating the Total Cost Per Hectare Per Year.

Assumption:

i) Total yield for high yielding area is 27.2 metric tons f.f.b/ha. yr. (Wakefield, 1980)

ii) Time taken to obtain 27.2 tons per hectare per annum at 2 min "harvesting stop" and 3 mph "travelling speed" and 50 rounds of harvesting per annum (Wakefield, 1980) = 1523 minutes.

iii) Total cost of operating the machine is $0.195 per minute.

Total cost to harvest 27.2 tons per hectare per annum

= $0.195/min x 1523 minutes/ha. yr.

= $297.05

Collection of Loose Fruit

During harvesting, handling and transportation operations, ripe fruits become easily detached from the bunch. The number of loose fruits varies with the degree of bunch ripeness and the height of the palms. The fresh fruit bunch will exert a greater impact as it hits the ground, thus producing more loose fruits. Zakaria (1980) reported that different types of containers -- such as baskets, sacks, nets or wheel barrows -- are usually used for collection of loose fruit.

The picking of loose fruit can be the most time consuming operation, and probably increases with age and, consequently, the height of the palms. Between 25 to 39 percent of the harvesters' time is involved in the operation. The variation in the time is probably due to the differences in condition of the estates being studied.

It has been suggested that the collection of loose fruit should be done by a separate team. In this manner, the harvesters' skill in cutting will be fully utilized and more productive.

Introduction of mechanical collection of loose fruit or improved methods in harvesting and handling of fruit bunches to reduce shattering of loose fruit could improve the rate of production. Zohadie and Wan Ishak (1982) suggested the use of a dump-truck to collect the bunch after cutting without letting it fall on the ground. This will eliminate the process of collecting the bunch and loose fruit manually. Spreading of nets and plastic or cloth have also been suggested and have been found to be effective. Further investigation should be done in order to reduce losses and increase productivity.

Infield Collection and Transportation

Infield transportation is classified as part of the harvesting operation. Infield transportation is the operation in which the fresh fruit bunches are carried from the palm immediately after harvesting to the collecting points along the roadside. The main objective of an infield transportation system should be to maintain the maximum quality of high-quality palm oil and to utilize all the available resources -- particularly the labor force and equipment -- most efficiently.

Because of the decrease in the labor force and the relatively few pieces of infield transport equipment available, immediate attention is required to develop a more suitable system for infield collection that will increase productivity and improve the quality of palm oil. Various systems of infield transportation have been tried, and a few such systems have been adopted. These include the jackpak, forklift, dump-truck and the buffalo-drawn sledge. An increase of more than 50 percent of harvesters' output is possible by using one of these machines (Webb, 1976).

Traditional Method

The traditional method of transportation for f.f.b. from the palm to the roadside is for a worker to carry the fruit bunches either in baskets or gunny sacks tied to a shoulder stick, or even carry the fruit bunch on his head. Bicycles and wheel barrows are two means of improving the traditional method of transporting the f.f.b. Even though using both of these methods is still a tedious job, they have the advantage of helping the workers to travel to and from work quickly. Also, the returning journey after sending the f.f.b. can be completed in less time. Wheel barrows, both single and double wheeled versions, are popular in some places and can be towed behind a bicycle or a motorcycle. However, these systems are limited only to flat ground and can also be hazardous to use.

Animal Powered System

This system of transportation utilizes a sledge or cart pulled by buffaloes for handling f.f.b. on relatively flat, low lying, and wet areas. By implementing this method, a reduction of about 34 percent in harvesting costs per ton of f.f.b. can be expected (Wan, 1973). A study on the rate of production also shows that a strong worker, unassisted, can handle 18 bunches per hour as compared with 24 bunches per hour by using this system.

There are three main components for the construction of this system. First, buffalo is required as the source of power. The buffalo should be well-built (with a powerful neck), healthy, and well-trained for pulling loads. Second, a harness, which is made up of a wooden yoke, fits on the buffalo's neck and connects the sledge to the buffalo. Third, the container in which the fruit is handled is known as a sledge. It is made of galvanized pipe, welded together, and is equipped with a wooden floor and wire netting affixed to the sides. These sledges are available in two sizes: the standard size and king size models. Figure 13 shows a diagram of a standard size sledge.

Despite its attractive low cost per ton, the adaptability and suitability of this system is limited to flat or gently undulating areas. It is not suitable for very hilly conditions or on peat soil. Also, there is some increase in liability if the animal is sick or wounded and additional management is needed to look after the animals.

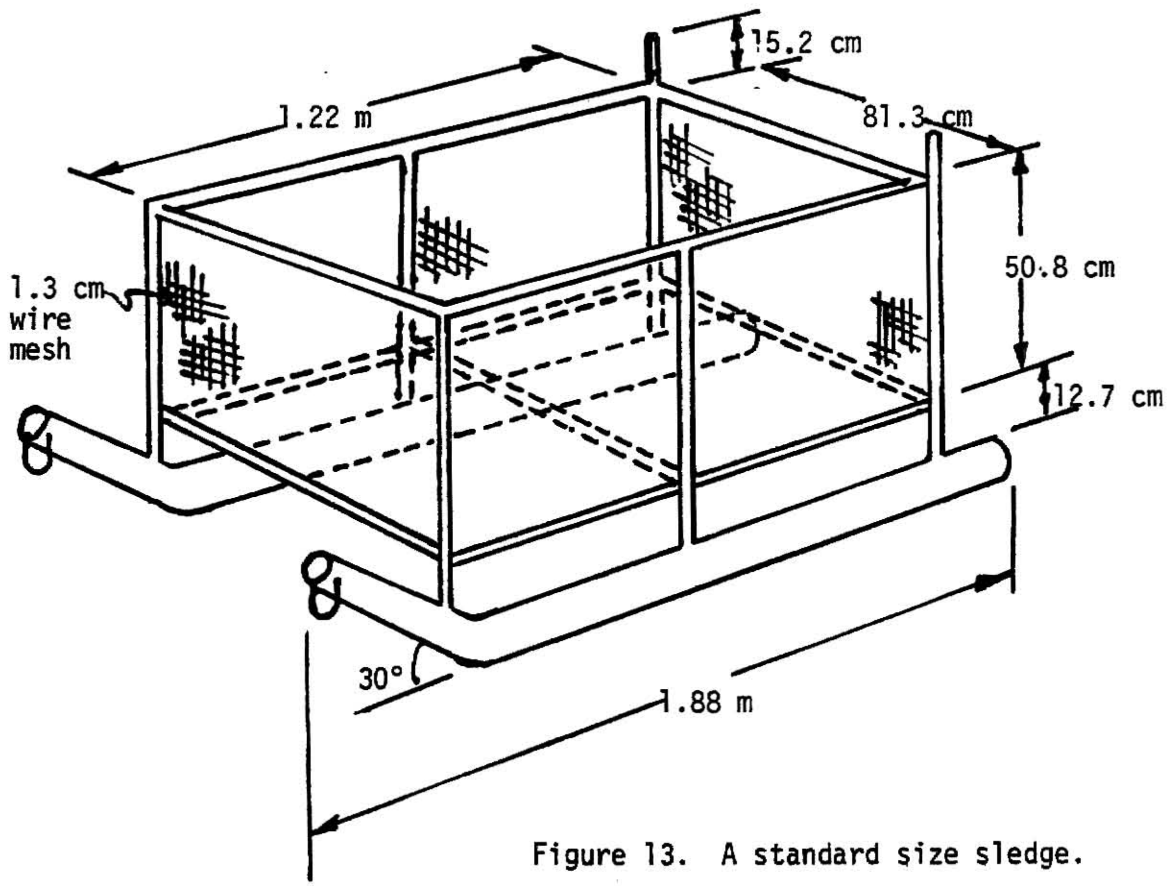


Figure 13. A standard size sledge.

Mechanized Infield Transportation System

With the advance in technology and reduction in labor force, various machines have been developed and some have been found to be very efficient. In developing a successful mechanized transportation system, the machine should possess most of the following criteria (Wan Ishak, 1980).

i) small rather than large size.

ii) low initial and operating costs.

iii) easy to operate and maintain.

iv) highly maneuverable.

v) has the ability to perform other funtions and have wider application.

vi) capable of maintaining the quality of the fruit by reduced handling.

The Jackpak. The jackpak container system runs on three wide, low pressure tires, is driven by 5 hp. diesel engine, and hydraulically lifts the containers to a height of about 15 cm., carrying them at speeds up to 12 miles per hour. Figure 14 illustrates a jackpak at work.

The jackpak is very suitable for use on flat or gently undulating land (Cunningham, 1969). However, only under the most ideal conditions did the vehicle operate effectively along palm rows. A path has to be prepared where the ground condition is uneven, or too soft, or where a large number of drains are present.

The handling capacity is approximately 25 tons f.f.b. per day; this would be equivalent to one machine per 260 to 300 hectares of mature palms (Zakaria, 1980). A more detailed feasibility study should be conducted on this system under various field conditions and terrains.

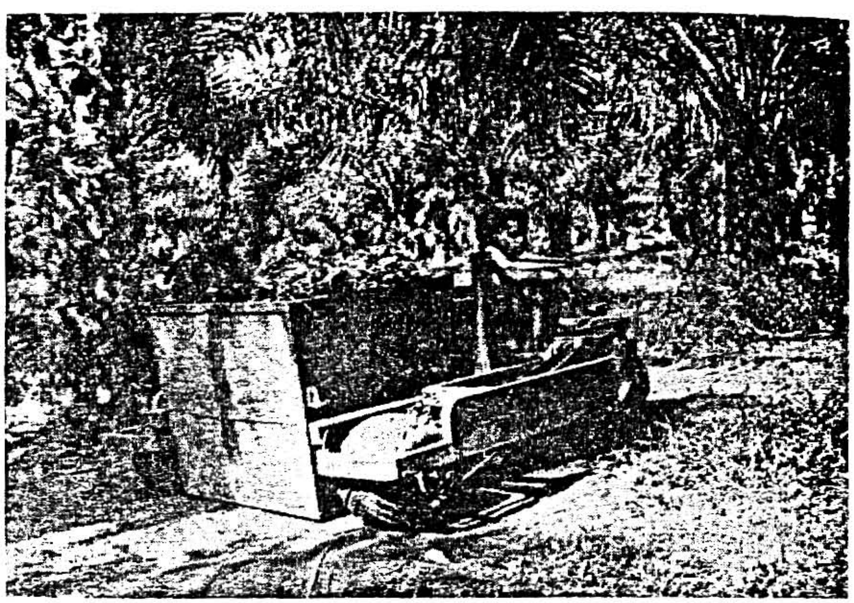


Figure 14. The 'Jackpak' used for infield transportation.

Tractor fitted with a Forklift Attachment. This is a four wheel-drive articulated chassis steering unit which is modified to enable f.f.b. collection near the point where cutting of the palm occurs. The forklift can be modified (with a skip of about one ton carrying capacity) and can then be raised to bunch height after the frond has been removed. By placing the lip of the skip just below the bunch, the harvester can then cut the stalk and the bunch together, thereby collecting the loose fruit without bruising or time loss.

If this system is used, tractor mounted cranes and nets are no longer necessary, as the forklift can lift a container of f.f.b. over the top of a conventional trailer, and discharge the fruit into the trailer. This system can reduce labor requirements by about 13 percent but harvesting costs will increase to about 30¢ per ton due to high capital costs (Zakaria, 1980).

Dump-truck. The dump-truck is an infield vehicle which can operate on a normal harvesting path preceded by the loader, which places the bunches and fruit into the hopper as the vehicle moves along. The loose fruit should be collected and placed in baskets before the dump-truck makes the pass. After emptying, the baskets are stacked behind the hopper. With this system, the construction of ramps for loading into trailers or lorries is required.

A test of a dump-truck on a flat land estate on the west coast of Malaysia indicates that a saving of 25 percent could be made in the harvesting cost. The harvesting cost when using the dump-truck is $4.25 per ton of f.f.b. as compared to $5.58 per ton f.f.b. for manual harvesting (Webb, 1976).

The dump-truck has several advantages over the other infield transportation systems. Some of the advantages include relatively low initial cost, high maneuverability, good traction, less soil compaction due to light weight of equipment, and reliable and easy operation and maintenance (Webb, 1976).

In order to increase the efficiency of the dump-truck, Zohadie and Wan Ishak (1982) have made some modifications on three major sections of the dump-truck, namely, the hopper for collection, the operator space for safety and the driving wheels for better traction (Figure 15). With this modified dump-truck, the fruit bunch can be collected directly after cutting without letting it fall on the ground. This will eliminate the process of collecting the fruit bunch and loose fruit manually.

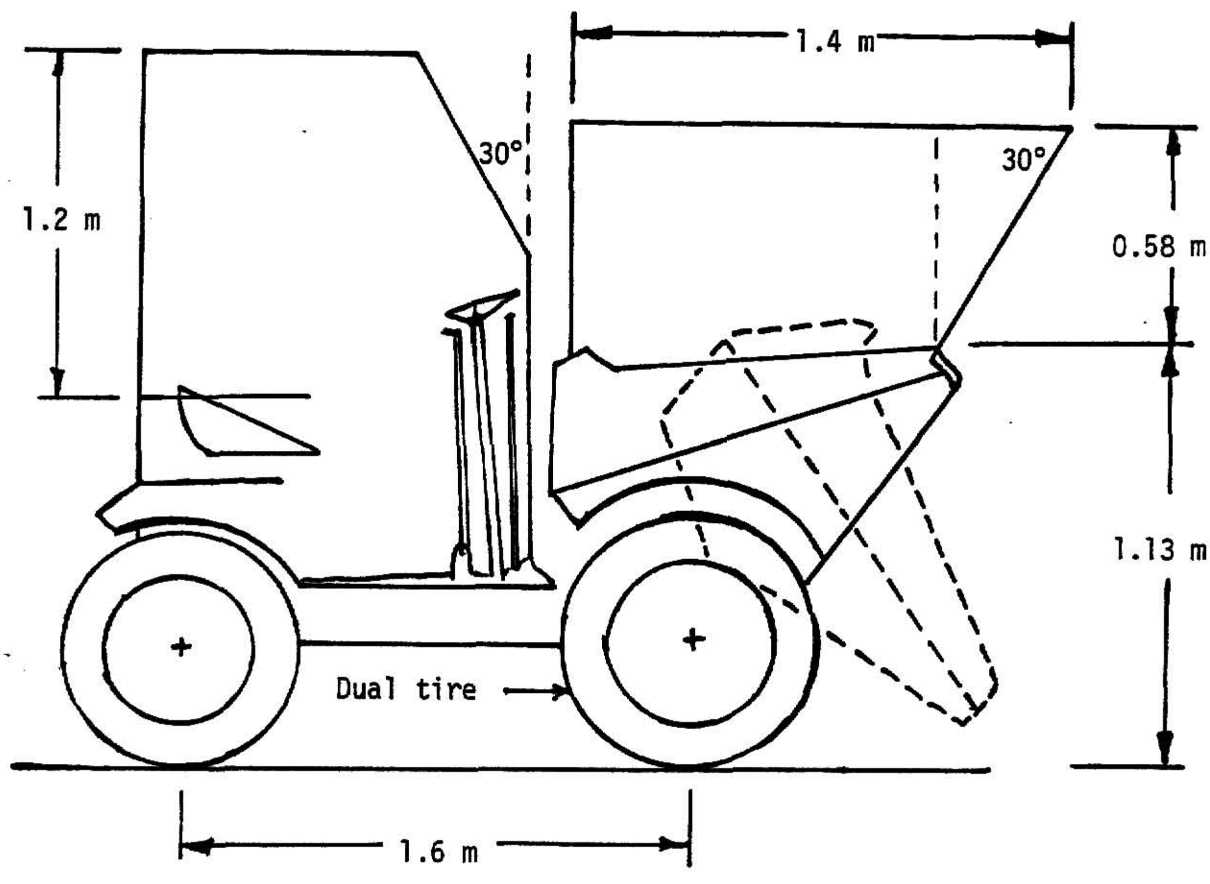


Figure 15. Configuration and dimensions of a modified dump-truck

Main-line Transportation System

The purpose of the main-line transportation system is to carry the anticipated f.f.b. from various collecting points in the fields to the palm oil mill where it is to be processed. This system must be organized so that the freshly-harvested crop starts to arrive at the mill as early in the day as possible, and in sufficient quantity to allow milling to commence. From then on, an adequate flow of f.f.b. must be maintained so that milling can continue without interruption.

Since there is a wide variation of conditions existing on oil palm estates, many different systems have been developed. These include lorries, tractor trailers, railway containers and sterilizer cages. However, the suitability of each individual system depends on various factors such as land topography, initial and operating costs and also the productivity of the system.

Lorries

With this system, a tipper lorry fitted with a crane is used to mechanically loading the f.f.b. It has been found that a unit composed of the following equipment can lift up to 60 tons of f.f.b. in 24 hours and deliver this crop to the mill (Price and Kidd, 1972).

1) One lorry (model Bedford KGLC 60) fitted with tipping gear, a specially fitted steel body, cab modifications, etc.
2) A crane (model Hiab) fitted to the lorry.
3) Net distribution vehicle.
4) 120 f.f.b. nets.

Besides the above equipment, a unit of the system also requires three workers-- the driver, lorry attendant, and the net distributor.

Loading is carried out by hooking the net to the crane extension boom (this is done by the net distributor), lifting the net load, and loading into the lorry. The lorry driver operates the crane while the lorry attendant in the back of the lorry unhooks the nets for fruit discharge, and also assists in stacking fruit as the lorry fills.

The technique is simple, very rapid and most attractive cost-wise. A cost analysis made by Price and Kidd (1972) in 1971 shows that the average transport cost per ton and the average loading cost per ton are $2.75 and $1.33 respectively (Appendix 3).

Tractors and Trailers

The technique of using a tractor fitted with a crane to load and empty the fruit loading nets into trailers is similar in many respects to using a lorry, described above. The only characteristic that differs is that only one tractor fitted with a crane is required for loading purposes and this tractor's function is solely to load the trailers while another tractor is fully employed in towing the filled trailers to the mill and returning the empty trailers to the field for re-filling.

The equipment required for this system are as follows:

One tractor (MF 165) with a rear mounted Hiab crane.

One tractor (MF 135) for towing trailers to and from the fields to the mill, and returning to the field.

Six - 5/6 tons rear tipping trailers.

150 fruit loading nets.

One motorcycle (Honda 175 c.c.) with sidecar attachment for net distribution.

Two tractors(MF 135) used for towing purposes during peak cropping periods.

In order to determine the cost of employing this system of transportation, a detailed study of all the capital and operating costs should be conducted. Adapting this system is useless unless it proves to be more profitable thanother systems.

Light Railway Systems

Transporting the f.f.b. from the field to the mill by means of a light railway system is a technique practiced even before the Second World War. During that period of time, labor, construction, and maintenance costs were very low. Nowadays, the high capital cost of this system is considered prohibitive, unless a detailed study of the production costs proves otherwise. An economic feasibility study by the United Nations Industrial Development Organization (UNIDO, 1974) shows a realistic cost comparison between the road and rail transport system. It was found that on coastal areas, establishing a light railway system is cheaper than the road network system. By using the light railway system, the actual cost per ton-kilometer of f.f.b. moved would be $0.263 as compared to $0.266 using the road network system (Appendix 4).

Improvements as well as modifications on the existing railway system are still beingcarried out in order to make the system more productive. Stimpson (1980)has successfully developed a gantry crane and specially designed a trailer chassis to carry the dismounted cage, which is tractor towed.

Briefly, the operation of the railway network system is as follows. An empty cage is placed on a trailer and towed to the various collecting points within the block. Cut bunches and bags of loose fruit are then loaded into the sterilizer cage. Once the cage is full, the tractor drives off to the gantry to transfer the filled cage to a railroad cart and to collect an empty cage. This process is repeated until collection is completed in the field, after which the tractors and gantry trailers move to the next field, one of them towing the gantry crane.

In spite of its high capital cost, this system has some advantages:

a) It reduces the labor requirement for the collection of f.f.b. and eliminates unpopular long carries, especially in fields having high average bunch weights.

b) It improves the quality of the f.f.b. arriving at the mill, especially when a very high standard of fruit ripeness is practiced.

c) It increases the productivity of the collectors involved.

Road Network System, Using Sterilizer Cages

In Malaysia, oil palms are grown under a wide variety of soil conditions. In some areas, the topography and the friable soil types contribute to a poor load carrying capacity, thus preventing the utilization of most heavy equipment. In this case, the collectors leave the fruit bunches and bags of loose fruit at predetermined collection points along the roadsides, and separate loading teams, paid on contract, accompany the tractor trains to load the bunches and loose fruit manually into the 2 1/2-ton sterilizer cages. The top rims of these cages are about 1.7 meters above the ground level, since the trailers were designed to have maximum clearance for easier loading.

However, with this system certain changes on the road layout have to be made. All sharp corners in the estate roads were widened, and those with culverts were extended in order to provide for the wide turning circles which these tractor-trains require.

No operation is considered successful unless it is economically feasible. A summary of the cost of this operation by Stimpson (1980) indicates that the all-in cost per ton of f.f.b. in 1971 was $2.50. It should be noted that the cost mentioned above does not apply to all situations. The distance between the plantation and the mill has a great influence on the cost of transportation. Another study done by UNIDO (1974), which took into account the distance between the field and mill, indicates that the actual cost per ton-kilometer is $0.266 (Appendix 5).

XIV COSTS OF PRODUCTION

Operations	Traditional (Manual) Method ($/ha.-yr.)	Improved or Partially-Mechanized Method ($/ha.-yr.)	Fully-Mechanized Method ($/ha.-yr.)
A. FIXED COSTS			
1. Land clearing	352.61	416.33	570.82
2. Lining and Holing (manual) 6.42 man-days @ $20.00/day	128.40	128.40	128.40
3. Planting material 160 seedlings/ha. @ $2.00/seedling	320.00	320.00	320.00
4. Planting from polybag (manual) 16.56 man-days/ha. @ $16.00/day	264.96	264.96	264.96
5. Drain construction:			
Outlet drain - using backhoe 10 m/ha. @ 10 m/hr. @ $20.00/hr	20.00	20.00	20.00
Collection drain - using backhoe 25 m/ha. @ 25 m/hr. @ $20.00/hr	20.00	20.00	20.00
Field drain - using ditcher 157.5 m/ha. @ 75 m/hr. @ $10.00/hr		21.00	21.00
Field drain - manual $44.10 per 75 m x 157.5 m	92.61		
6. Road construction	425.00	425.00	425.00
TOTAL FIXED COSTS	1623.58	1615.69	1770.17
ANNUAL FIXED COSTS PER HECTARE	54.12	53.86	59.00

COSTS OF PRODUCTION (CONT.)

Operations	Traditional (Manual) Method ($/ha.-yr.)	Improved or Partially-Mechanized Method ($/ha.-yr.)	Fully-Mechanized Method ($/ha.-yr.)
B. OPERATING COSTS (for 9-year old palm)			
1. Field maintenance 34.6 man-days/ha-yr x $16.00/day	553.60	553.60	553.60
2. Pruning 4.4 man-days/ha-yr x $10.00/day	44.00	44.00	44.00
3. Assisted pollination 72 rounds/yr x $5.00/round	360.00	360.00	360.00
4. Diseases and pests control $0.0088/kg x 27200 kg	239.36	239.36	239.36
5. Fertilizers $22.00/ha-month x 12 months	264.00	264.00	264.00
6. Cutting and collection of loose fruit	214.10	199.10	297.05
7. Infield transportation	240.00	175.00	185.50
8. Main-line transportation $0.787/ton-mile x 27.2 ton/ha-yr x 20 miles	428.13	428.13	428.13
TOTAL ANNUAL OPERATING COSTS PER HECTARE	2343.19	2263.19	2371.64
TOTAL ANNUAL PRODUCTION COSTS PER HECTARE = Annual fixed costs + Annual operating costs	2397.31	2317.05	2430.64

XV. CONCLUSION

The oil palm industry has mechanized several operations through the years. Various existing systems appear suitable; some being assessed look promising. There is, however, a need to investigate or to introduce new systems or improve on existing ones in order to enhance cost efficiency and reduce dependence on an input that is becoming scarce and costly: labor.

From the cost analysis of the different harvesting operations, it was found that, at present, using the improved methods of harvesting will result in less total cost and greater profit. However, the fully-mechanized methods will probably in the future be more feasible when labor becomes more costly and more reluctant to perform the tedious manual and improved methods of harvesting.

REFERENCES

1. Adham, A. (1980). Mechanization of drain construction and maintenance in the oil palm industry. In PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December 1980. Kuala Lumpur, Malaysia.

2. Alexander, D.B.W. (1952). A method of pollinating dates. Report of 29th. Annual Date Growers' Institute, Coachella, California. 1952. p. 20

3. Arunlandi, K. (1971). Observations on the control of leaf-eating caterpillars in oil palm. Preceeding of Conference on Crop Protection in Malaysia 1972. Incorporated Society of Planters, Kuala Lumpur. p. 116

4. Balakrishnan, V. and C.L. Lim (1976). Jungle clearing by FELDA for planting oil palm. Proceeding of Malaysia International Oil Palm Conference 1976, Kuala Lumpur.

5. Bloomfield, A. and K.M. Khoo (1975). Mechanization of estates spraying. Proceeding of Conference on Estate Engineering and Mechanization, 1975. Incorporated Society of Planters, Kuala Lumpur.

6. Chan, C.L. (1980). Problems and possible solutions of mechanized application of fertilizer and pesticides in oil palm. In PORIM Workshop on Farm Mechanization on the Oil Palm Industry - December, 1980. Kuala Lumpur, Malaysia.

7. Chang, K.C. (1980). Problems and possible solutions of land clearing for planting or replanting oil palm. In PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December, 1980. Kuala Lumpur.

8. Cunningham, W.M. (1969). A container system for the transportation of oil palm fruit. Progress in oil palm (ed. P.D. Turner) pp 287-301. Kuala Lumpur: Incorporated Society of Planters.

9. Department of Statistics Yearbook, (1977) Department of Statistics Kuala Lumpur.

10. Galenson, A. (1980). Malaysia - Growth and Equity in a Multi-racial Society. The johns Hopkins University press, London. p 211-252

11. Hansen, V.E. et al. (1980). Irigation Principles and Practices. (4th. Ed.) John Wiley & Sons. New York.

12. Harrisons & Crosfield Agency (1980), Kuala Lumpur, Malaysia.

13. Hartley C.W.S. (1967). The Oil Palm Longmans, Green and Co. Ltd., London.

14. Joseph, Pomerez, Prince and Sacher (1966)
Physics for Engineering Technology. John Wiley & Sons, Inc.

15. Malaysia Agricultural Producers' Association Annual Report (1973-1979), M.A.P.A., Kuala Lumpur, Malaysia.

16. Malaysia Economics, 1982.
Department of Economics, Kuala Lumpur, Malaysia.

17. Monthly Statistical Bulletin, (April 1980).
Department of Statistics, Kuala Lumpur, Malaysia.

18. Oil Palm, Coconut & Tea Statistics Handbook (1972-77). Department of Statistics, Kuala Lumpur, Malaysia.

19. Peter, P. (1980). Malaysia-Growth and Equity in a Multi-racial Society The Johns Hopkins University Press, London. p 269-273

20. Price, J.G.M. and P.P. Kidd. (1972). Mechanized loading of f.f.b. and transportation from field to palm oil mill. Reprint from international Oil Palm conference, Kuala Lumpur. 1972.

21. Rajaratham, J.A. and K.W. Chan (1977). Trials on aerial application of fertilizers to oil palm. Preceeding of Seminar on Agricultural Aviation, 1977. Kuala Lumpur.

22. Sanker, N.S. (1966). Fruit Collection and Evacuation by Road. Planter Kuala Lumpur, Malaysia. 42 : 59 - 68

23. Stimpson, K.M.S. (1980). Aspects of mechanization on oil palm estates In PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December 1980. Kuala Lumpur, Malaysia.

24. Tam, T.K. (1980). Mechanization of oil palm estates - present situation and possible future developments. IN PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December 1980. Kuala Lumpur. Malaysia.

25. United Nations Industrial Development Organization (UNIDO, 1974). Technical and Economic Aspects of the Oil Palm Fruit Processing Industry, New York.

26. Wakefield, O.F. (1980). Factors affecting the viability of mechanizing oil palm harvesting operations. In PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December 1980. Kuala Lumpur, Malaysia.

27. ---------, and S. Nadarajan. (1979). Mechanized Fertilizer Application on Coastal Estates. Planter Vol. 55, No.634, p.25

28. Wan, D. (1973). The use of buffaloes in oil palm fruit collection In - Advances in Oil Palm Cultivation (ed. R.L. Wastie and D.A. Earp). - Incorporated Society of Planters, Kuala Lumpur. pp. 432-437

29. Wan Ishak (1980). Oil palm mechanization in relation to infield transportation. In PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December 1980. Kuala Lumpur, Malaysia.

30. Webb, B.H. (1976). The development of suitable infield f.f.b. harvesting systems to improve the efficiency of oil palm production. In Malaysian International Agricultural Oil Palm Conference 1976.

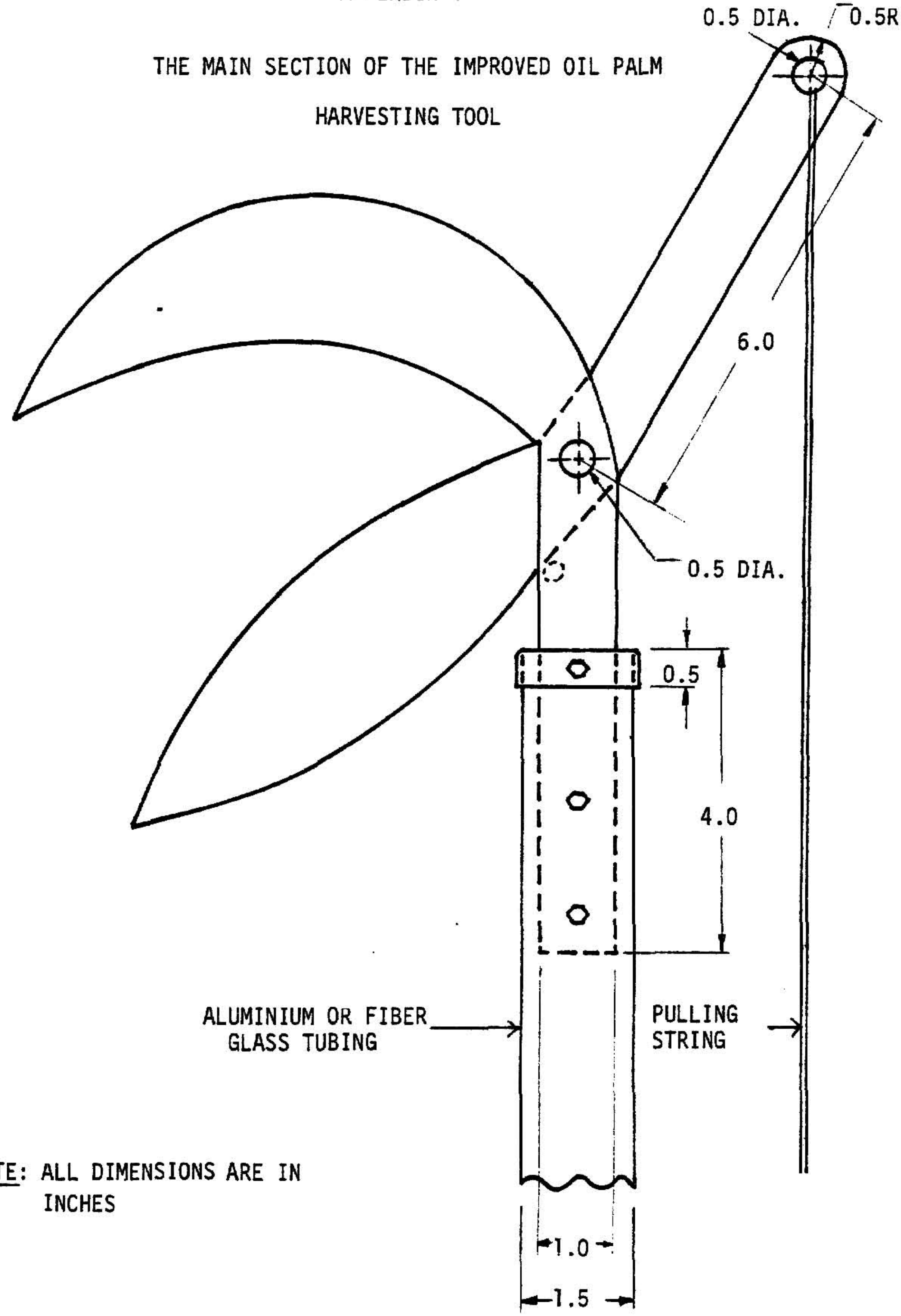
31. Zakaria, A.A. (1980). Problems and possible solutions of oil palm harvesting and infield transportation. In PORIM Workshop on Farm Mechanization in the Oil Palm Industry - December 1980. Kuala Lumpur, Malaysia.

32. Zohadie, B. and W.I. Ishak (1982). Mechanization of oil palm fruit harvesting and transportation in Malaysia. In Agricultural Mechanization in Asia, Tokyo. Summer 1982. p. 31-34

APPENDICES

APPENDIX 1

THE MAIN SECTION OF THE IMPROVED OIL PALM HARVESTING TOOL

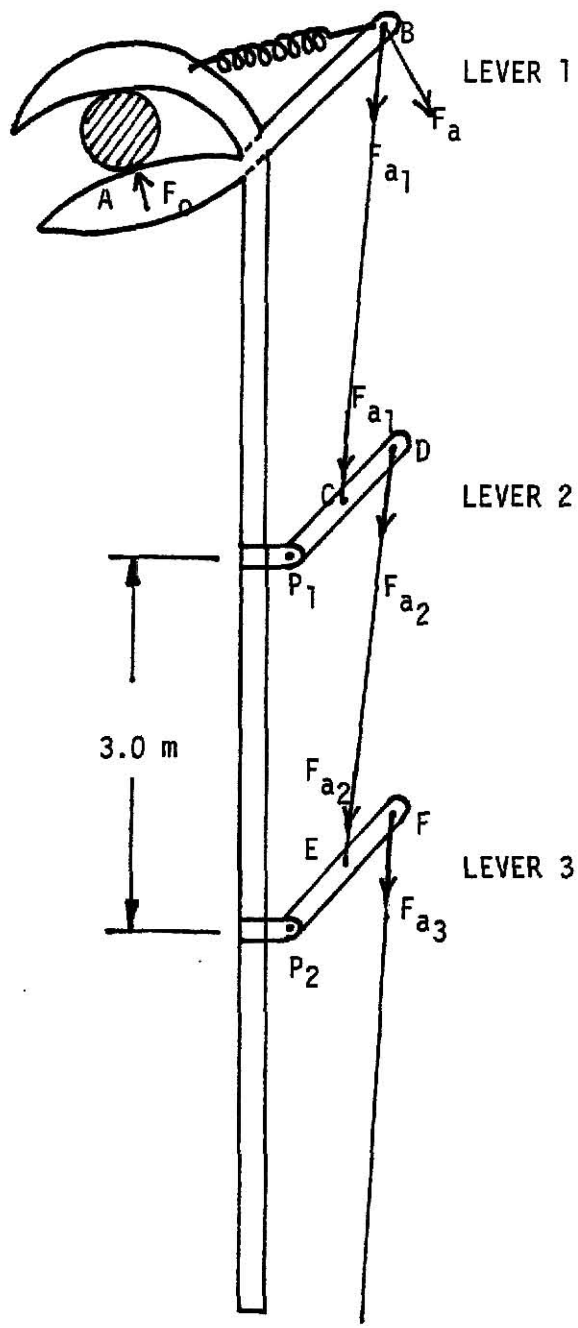


NOTE: ALL DIMENSIONS ARE IN INCHES

APPENDIX 1 (CONTINUED)

SKETCH DRAWING OF THE IMPROVED OIL PALM

HARVESTING TOOL



Calculating The Force Required

Joseph, Pomeranz, Prince, and Sacher (1966) state that with 100 percent efficiency, output force times distance is equal to input force times distance.

$$\text{Efficiency} = \frac{F_o \times S_o}{F_i \times S_i}$$

where F_o - output force

S_o - output distance

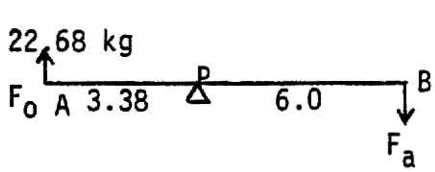
F_i - input force

S_i - input distance

In calculating the force required, a few assumptions were involved:

1. The efficiency is assumed be 80 percent.
2. The weight of the equipment and the friction at the pivot is to be neglected.
3. The force needed to stretch the spring is also to be neglected.
4. The initial force to cut the bunch is estimated to be 22.68 kilogram-force.

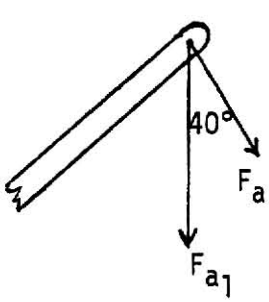
At Lever 1



$$F_o \times AP = 0.8(F_a \times BP)$$

$$F_a = \frac{F_o \times AP}{0.8 \times BP} = \frac{22.68 \times 3.38}{0.8 \times 6}$$

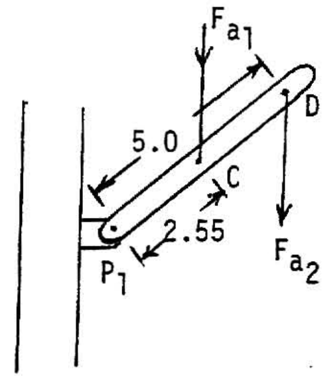
$$= \underline{15.97 \text{ kgf}}.$$



$$\text{Cos } 40° = \frac{F_a}{F_{a_1}}$$

$$F_{a_1} = \frac{F_a}{\text{Cos } 40°} = \frac{15.97}{0.766} = \underline{20.85 \text{ kgf}}.$$

<u>At Lever 2</u>

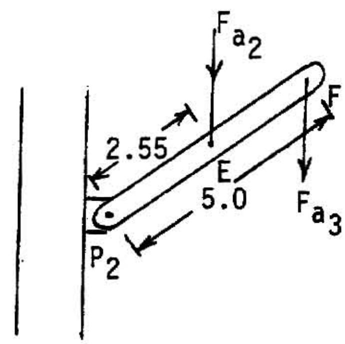


$$F_{a_1} \times CP_1 = 0.8(F_{a_2} \times DP_1)$$

$$F_{a_2} = \frac{F_{a_2} \times CP}{DP_1 \times 0.8} = \frac{20.85 \times 2.55}{5.0 \quad 0.8}$$

$$= \underline{13.29 \text{ kgf.}}$$

<u>At Lever 3</u>



$$F_{a_2} \times EP_2 = 0.8(F_{a_3} \times FP_2)$$

$$F_{a_3} = \frac{F_{a_2} \times EP_2}{0.8 \times FP_2} = \frac{13.29 \times 2.55}{0.8 \times 5.0}$$

$$= \underline{8.47 \text{ kgf.}}$$

Conclusion:

From the improvement made to the traditional equipment, the force required to do the work is reduced from 22.68 kgf. to 8.47 kgf.

APPENDIX 2

MACHINE COSTING WORKSHEET

Capital Cost	$	30,000
Salvage Value - 20 percent of Capital Cost	$	6,000
Annual Use - 8 hours x 25 days x 12 months	$	2,400
Maximum Life	YRS	5
Maximum Life	HRS	12,000
<u>FIXED COSTS - OWNING COSTS</u>		
Depreciation	$	4,800
Interest - 10 percent Average Value	$	1,800
Insurance - 0.6 percent of Capital	$	180
Total Fixed Cost	$	6,780
<u>VARIABLE COSTS - OPERATING COSTS</u>		
Repairs, Maintenance and Lubricants	$	7,200
Fuel Cost - $1.80 per gallon	$	4,320
Labour - 2 men x $400 per month	$	9,600
Total Variable Cost	$	21,120
Total Cost Per Year	$	27,900
Cost Per Hour	$	11.62
Cost Per Minute	¢	19.5

APPENDIX 3

COST-ANALYSIS FOR MAIN-LINE TRANSPORTATION SYSTEM USING LORRIES

The costs set forth here have been consolidated over the whole of 1971 for an estate about 30 kilometers distant from the oil mill. All vehicles operate with road licences.

One Bedford KGLC 60 fitted with SL 7 tipping gear, specially fitted steel body, cab modifications, etc.	$ 26,600
Hiab crane and fitting charges	7,500
Net distribution vehicle	3,500
120 f.f.b. nets	9,600
	$ 47,200

Average costs for 1971:

1) Transport cost per metric ton................$2.75

The following have been included in the transport cost per metric ton:

a) Lorry drivers' and attendants' wages
b) Repairs and maintenance charges on lorries, including tires.
c) Depreciation charges on lorries.
d) Insurance and road tax on lorries.
e) Fuel and lubricants.

2) Loading cost per metric ton................ $1.33

The following have been included in the loading cost per metric ton:

a) Net distribution van drivers' wages.
b) Repairs and maintenance charges on van, including tires.
c) Depreciation charges on vans.
d) Fuel and lubricants.
e) Insurance.
f) Crane depreciation charges.
g) Crane operation charges.
h) Net depreciation
i) Net repairs.

APPENDIX 4

LIGHT RAILWAY SYSTEM

In order to serve efficiently, the railroad track must be established at a density of 0.019 kilometer per hectare. The following is an example extracted from a study by UNIDO (1974) on a 4,047 hectares estate yielding 100,000 metric tons of f.f.b. per year. The f.f.b. is being hauled an average of 11.3 kilometers.

The investment required for a railway system for a 4,047 hectares oil palm estate would be as follows:

80.45 kilometers of track	$ 1,250,000
96.54 kilometers of secondary roads	$ 240,000
10 five-ton diesel locomotives	$ 300,000
134 cages and trucks	$ 227,800
5 tractors and trailers	$ 75,000
5 gantries	$ 30,000
5 platform trollies	$ 6,000
1 tank wagon	$ 6,000
Total	$ 2,134,800

The following are the fixed operating costs of a railway network system:

<u>Fixed Costs:</u>

1) Depreciation

5 percent on 80.45 km of rail track ($1,250,000)	$ 62,500
5 percent on 96.54 km of secondary roads ($240,000)	$ 12,000
7.5 percent on rolling stock ($269,800)	$ 20,325
10 percent on locomotives ($300,000)	$ 30,000

Fixed Costs (cont.)

2) Interest

8 percent on locomotives ($2,134,800)	170,780
Total Fixed Costs	295,609

Operating Costs:

Railways transport and upkeep of locomotives	55,000
Upkeep of rail tracks	25,000
Upkeep of rolling stock	10,000
Total Operating Costs	90,000
TOTAL ANNUAL COSTS	385,609

The actual cost per ton-kilometer of goods moved would be:

$$\frac{\$385{,}609/\text{yr}}{130{,}000 \text{ tons} \times 11.3 \text{ km.}} = \$0.263$$

APPENDIX 5

ROAD NETWORK SYSTEM

The road network on coastal clay soil should be established at a density of 50 meters per hectare (66 feet per acre). Seventy percent of the road network consists of all-weather roads with mine tailings as ballast, while 30 percent of the road network consists of secondary roads. A total of 140 kilometers of all-weather roads and 60 kilometers of secondary roads will be required on 4,047 hectares estate (UNIDO, 1974).

The total capital cost of a road network collecting system would be as follows:

140 kilometers of all-weather roads	$	870,000
60 kilometers of secondary roads	$	152,000
Loading ramp and shunting area	$	100,000
100 fruit cages and underwagons	$	120,000
10 tractors	$	250,000
20 6-ton trailers	$	120,000
Total	$	1,612,000

The followings are the fixed and operational costs of a road network system:

<u>Fixed Costs</u>:

1) Depreciation

5 percent on roads ($1,022,000)	51,100
5 percent on loading ramp ($100,000)	5,000
10 percent on cages and underwagons ($120,000)	12,000
15 percent on tractors and trailers ($370,000)	55,500

Fixed Costs (cont.)

2) Interest

8 percent on capital ($1,612,000)	128,960
Total Fixed Costs	252,560

Operating Costs:

Upkeep of 200 kilometers of roads at $5 per 20 m	62,500
Upkeep of tractors and trailers	25,000
Tractor operating costs	50,000
Total Operating Costs	137,500
TOTAL ANNUAL COSTS	390,060

The actual cost per ton-kilometer of goods moved would be:

$$\frac{\$390{,}060}{130{,}000 \text{ tons} \times 11.3 \text{ km.}} = \$0.266$$

MECHANIZATION OF OIL PALM PRODUCTION IN MALAYSIA

by

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B. S., Iowa State University, Ames, Iowa, 1981

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

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Agricultural Mechanization

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1983

ABSTRACT

In an attempt to mechanize the oil palm production system in Malaysia, the author presents a general review and discusses the existing level of mechanization done for the various operations in the oil palm industry. In this investigation, more attention was given to the harvesting operations due to the fact that most of these operations are still being done by the traditional method. Information on the total acreage, production and price situation is also presented.

Current oil palm acreage in Malaysia probably exceeds one million hectares. Due to the favorable conditions of the country, increasing acreage of oil palms can be expected in the future. However, since the past few years, the oil palm industry is experiencing a shortage of labor force due to the migration of labor to larger cities. The extent of mechanization and the range of machinery and implements commonly used on oil palm plantations are reviewed under different job classifications from land preparation to planting, drain construction and maintenance, fertilizer and pesticides application, harvesting and transportation. Although, it may be more economical to perform the various operations by traditional methods, the increasing problem being faced is the shortage of labor. Thus, mechanization at some level needs to be considered for the future. Problems pertaining to mechanization are also mentioned. Some of the main constraints include high initial costs and the unsuitability of several machines for the local conditions.

Without a proper drainage system, it is almost impossible to establish an oil palm plantation on a flat coastal soil. In the study, it was found that the cost of constructing and maintaining the drains was lowest when using the backhoe and trencher. For fertilizer and pesticides application,

a comparison between field equipment and aerial operated equipment was conducted. It appears that the aerial method of application will be used to a greater extent by the oil palm growers in the future.

As a means to increase the productivity of labor and to increase the quality of palm oil, various methods of harvesting and transportation are discussed. The feasibility of mechanizing the harvesting operations was determined by classifying the operations under traditional or manual method, improved or partially-mechanized and fully-mechanized method. The economic analysis indicated that, at present, using the improved or partially-mechanized method shows a cost advantage over the traditional and the fully-mechanized methods. The cost per hectare per year using the improved or partially-mechanized method is $2,317.05 as compared to $2,397.31 and $2,430.64 for the traditional method and the full-mechanized methods, respectively.