# General Aspects on Cultivation and Processing of the Oil Palm

*(Elaeis guineensis Jacq.)*


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# Content

To our readers

*The oil palm (Elaeis guineensis Jacq.) is the base of a highly profitable agro-industry that attracts the attention of many potential investors, particularly nowadays with the high prices of petroleum derivatives that make rentable the production of biodiesel from palm oil. The literature on this crop is extensive, may be the most complete among tropical perennials. The objective of this publication is to make available to those interested for the first time in the crop, an introductory guide summarizing the most important aspects of the agro-industry.*

*This publication is based on a previous work "Apectos Generales de la Palma Aceitera" originally published in Spanish by R. Escobar in 1980. However, the whole work has been updated and new aspects have been added, such as the economics of the agroindustry.*

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## 1. Introduction

The oil palm is the most productive species among oleaginous plants. According to Jalani et al. (1993), under favorable conditions, a commercial plantation of this plant can produce an average of 4.5 t/ha/year of crude red palm oil, 0.5 t/ha/year of kernel oil, and 0.45 t/ha/year of kernel cake. This is about three times the coconut tree yields and about 10 times that of soybeans. This superiority of the oil palm over other oleaginous plants is illustrated in table 1. It is easy to conclude that the commercial cultivation of the oil palm is without doubt one of the best economical options for the humid tropics.

**Table 1.**
**Commercial productivity of several oleaginous crops**

| Crop | Oil (kg/ha/year) |
|---|---|
| Oil palm | 2,500 - 4,500 |
| Coconut tree | 600 - 2,500 |
| Rape seed | 600 - 1,000 |
| Olive | 500 - 1,000 |
| Sunflower | 280 - 700 |
| Groundnut | 340 - 440 |
| Soybean | 300 - 450 |

Source: Jalani, et al. 1993

The largest expansion of the crop occurred in Southeast Asia (Table 2), where about 10 times more land has been planted when compared with the American and Africa continents together.

The oil palm was introduced from Africa to Southeast Asia at the beginning of the XIX century, where the first commercial plantation was established in Tnah Itam Ulu, Indonesia in 1911. By the year 1915, the area planted had increased to 2,760 ha (Taniputra, et. al., 1988). Later, other countries started planting this new crop in large scale, mainly Malaysia, which became the industry's world leader. It is not easy to know all aspects that made of the oil palm a big success in Southeast Asia; however, abundant and cheap labor and highly favorable environmental conditions for the crop contributed greatly to this.

**Table 2.**
**Total area planted with oil palm**

| Geographical area | Total (000's of ha) |
|---|---|
| Asia | 8,692 |
| Africa | 810 |
| America | 781 |
| **Total** | **10,283** |

The history of the oil palm in the Americas goes back to 1926, when the Panama Division of the former United Fruit Company (UFCo), brought some seeds from Malaysia. Later in 1927, the Experimental Station of Lancetilla on the Atlantic coast of Honduras, imported seeds from Asia and Africa. In 1929, the Guatemala Division brought 1,000 seeds from Sierra Leone (Richardson, 1990). Open pollinated seeds were eventually distributed from Lancetilla to other countries in Central America (Guatemala and Costa Rica), the Caribbean (Cuba) and South America (Colombia, Ecuador and Peru).

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Despite these early efforts, the commercial development of the industry in America had a slow start when compared with Southeast Asia.

In Africa, water deficit and pests and diseases in some areas reduced potential yields and prevented the expansion of the industry. In this continent, oil is also obtained from wild groves which productivity is very low. This oil is normally consumed directly, without any further processing (refining) after extraction.

The oil palm industry generates numerous byproducts that add value along the chain of exploitation of the plant. The variety of products that can be obtained from the oil palm is very extensive, and includes edible and industrial oils and fats, vitamins (the oil is very rich is vitamins A and E), animal concentrates, soaps, detergents, cosmetics, lotions and even polyurethane. However, the attention of many investors is now concentrated in the alternative to produce biodiesel.

Originally, many commercial oil palm plantations were established in land claimed directly from virgin forests. However, the crop was also planted in areas that had been previously deforested and were with no use, creating new economical and social opportunities for whole communities.

In general terms, an oil palm plantation can be considered environmentally friendly, since the use of agrochemicals is limited when compared with most annual crops, it offers a permanent cover to superficial soil (reducing erosion), and many plant and animal species find refuge in it. The oil palm is particularly efficient taking up carbon dioxide: a hectare of oil palm can fix about 450 t of $CO_2$ from the atmosphere. Besides this, the crop requires about 19.2 GJ/ha to produce the equivalent to 182.1 GJ. This ratio is very favorable when compared with crops such as soybeans which energy demand is much larger to produce a particular output in terms of oil.

# 2. Economical importance of the oil palm

It is estimated that world vegetable oil production will be around 111 million tons for the period 2005-2006. Most of this oil will come from oil palm and soybeans (Table 3). The share for fats from animal origin, such as lard, shortening and fish oil, etc has been decreasing through the years.

**Table 3.**
**World production of vegetable oils**

| Industry | 2003-04 | 2004-05 | 2005-06 |
|---|---|---|---|
| Soybeans | 30.0 | 31.9 | 33.6 |
| Oil palm | 28.8 | 31.6 | 33.0 |
| Rape seed | 14.2 | 15.9 | 15.6 |
| Sunflower | 9.2 | 9.0 | 9.8 |
| Others | 18.5 | 19.5 | 19.5 |
| **Total** | **100.6** | **107.9** | **111.4** |

Source: VEGETABLE OILS: Competition in a Changing Market

# 3. The oil palm

The oil palm is the only tropical perennial that can be commercially harvested every 7-10 days. This means that commercial exploitation starts at 24-36 months after plantings and becomes a continuous process that can be extended for 25 or more years, when the whole plantation is usually renewed. This feature is very attractive to both small and big investors that appreciate to have a continuous cash flow.

### 3.1 Botany

The genus *Elaeis* has two species. From an economical point of view, the species *Elaeis guineensis Jacq*., or African oil palm is the most important. The other species is known as the American oil palm (*Elaeis oleifera*), which is normally found growing in the wild in Central and part of South America. This palm is of great interest for plant breeders since the inter-specific hybrid with *E. guineensis* (OxG hybrid) has some important economical characteristics, such a reduced stem elongation rate (short trunks), good oil quality (high content of unsaturated fatty acids) and resistance to some diseases. Despite these attractive characteristics, the OxG hybrids are not normally planted commercially, since even the best crosses now available are less efficient as oil producers when compared with the African oil palm. Besides this, such hybrids require additional management costs such as the need for assisted pollination. The rest of this document refers only to the African oil palm.

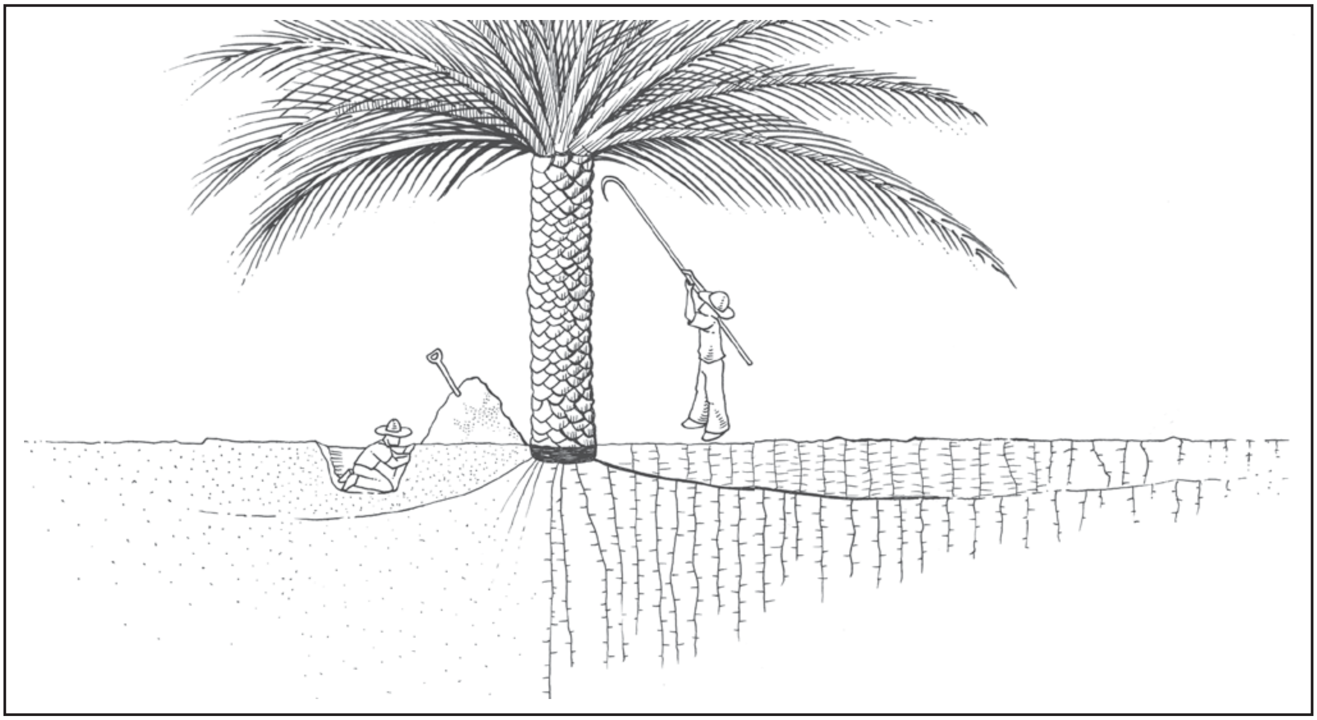

**Figure 1**. Root system of the African oil palm. Source: Jourdan and Rey, 1997 (Corley, R. H. V., 2003).

### 3.2 Root system

Roots of the oil palm form a thick superficial adventitious mat, concentrated within the first 30-50 cm of the soil profile. However, some roots may grow laterally 20 meters or more. (Figure 1).

The largest roots are called primary roots (average of 5 meters in length and 6-10 mm diameter). These originate directly from the plant base and give rise to numerous secondary roots (1- 4 mm diameter), which in turn form the tertiary roots (about 10 cm in length and 0.5 - 1.5 mm diameter), and finally the quaternary system (1-4 mm in length and 0.2 - 0.5 mm diameter)

The fibrous superficial root system makes this plant very sensitive to poor soil aeration caused by heavy textures, soil compaction and poor drainage. Besides this, a superficial tillage may severely damage the root system, particularly in young plantations. This is one of the reasons why intercropping is not favored by many.

### 3.3 Stem

The stem is formed by a central cylinder surrounded by fibrous tissue that gives consistency. At the tip, and surrounded by leaves lays a single growing point, named the apical meristem. The stem starts elongating when the plant is about three years old. From there, the elongation rate ranges between 35 and 70 cm per year depending on the variety and environmental conditions. The stem may reach 25 m or more in adult palms, but harvesting costs increase too much for palms 15 meters or taller; which is used as an indication to renew the plantation.

### 3.4 Canopy

Leaves are pinnate and grow from the stem forming spirals giving rise to a symmetrical canopy. The central unopened leaves are normally called "spears". The whorl is the package of youngest leaves. Leaf emission rate varies with palm age, variety and environmental conditions. Young palms may produce three or more leaves per month, but eventually leaf emission rate stabilizes at around two per month in adult plantations, when a palm may accumulate between 36 and 45 fully developed leaves, depending on pruning cycles and light competition (plant density).

In the species *E. guineensis*, leaflets are arranged in different angles and planes along both sides of the rachis. In *E. oleifera* and the O x G hybrids, leaflets are inserted in one single plane (Figure 2).

Any particular leaf has between 100 and 160 pairs of leaflets (length: 100-120 cm; width: 4 - 6 cm) that form about 12 m2 of photosynthetic tissue. Leaves measure 6-8 metes in length in most traditional varieties, but in the OxG hybrids may reach 10 or more meters.

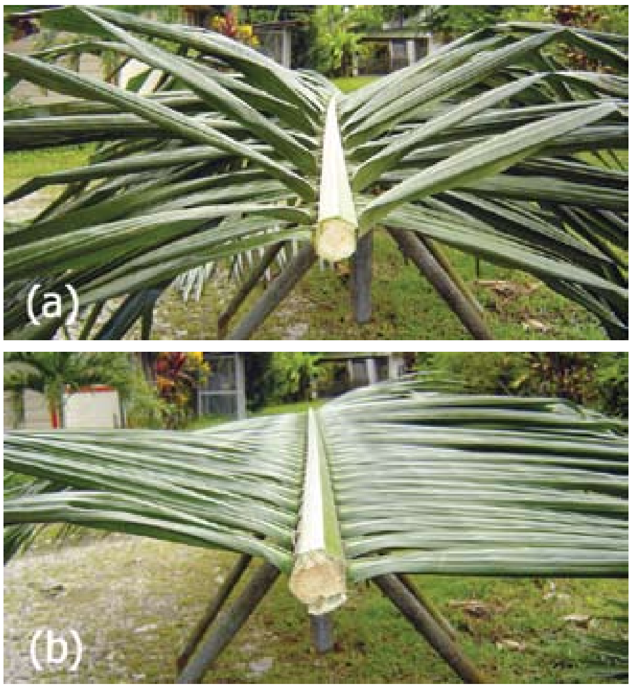


Figure 2. Leaflet arrangement along the rachis in *E. guineensis* (a) *E. oleifera* and OxG hybrids (b)

### 3.5 Reproductive system: inflorescences

The oil palm is a monoic species, which means that both male and female organs (inflorescences) are formed separately (normally in time and space). According to environmental conditions and management, female and males cycles are repeated; the persistence of male cycles indicates the presence of some sort of stress on the plant. The oil palm is a classical example of a cross pollinated species, where the pollinating agents are insects and wind.

Both male and female inflorescences are similar in its arrangement: there is a central axis (fibrous rachis), which originates numerous spikelets that bear the male or female individual flowers. These inflorescences are formed in the axils of the leaves, and when young are enclosed in two spates (fibrous sheaths) that open until the flowers are ready for anthesis (release of pollen or being pollinated)

A female inflorescence in an adult palm (about 8 years old) may have near 150 spikelets, each one bearing about 785 individual flowers. However, only 3,000-3,600 of the more than 10,000 initial flowers develop into normal fruits. Anthesis (receptive period during which pollination may occur) starts on the base of the spikelets toward its tip and is completed within 2-3 days. A male inflorescence may produce 25-100 grams of pollen, and anthesis also occurs from the base up. Most pollen is released during the first 3 days, but some may still be produced up to the fifth day of anthesis (Figure 3).

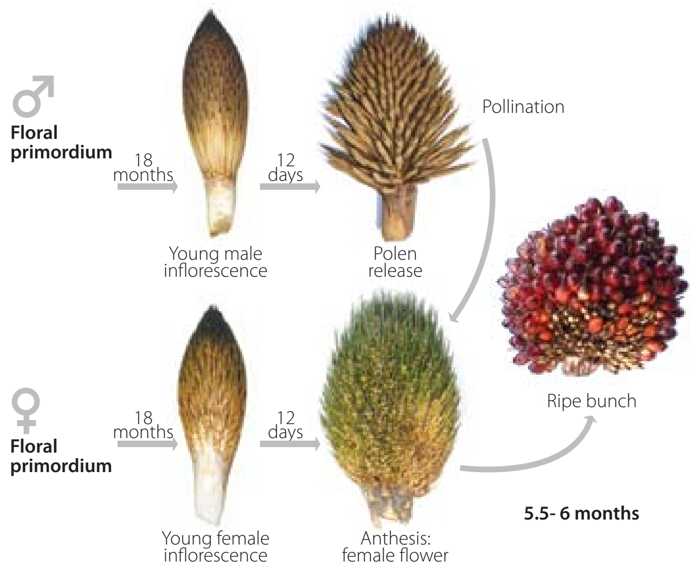


Figure 3. Reproductive behavior of the oil palm

### 3.6 Bunches and fruits

A bunch is fully formed about 5-6 months from pollination (anthesis). In a commercial plantation pollen normally comes from nearby plants (Figure 3). The ripe bunch has an ovoid shape, with numerous thorns (tips of the spikelets) on the surface that gives it a rough appearance. Both size and weight of the bunches increase with palm age, but bunch number per plant is reduced. On young palms, bunch weight is about 2.5-3 kg, but in adult palms, weight can be as high as 50 kg, but most frequently between 10 and 25 kg. Bunch size in adult palms is about 50 cm x 35 cm.

The number of bunches produced per palm during the year varies according to age, environment, management and variety. In average, an adult palm may produce between 8 and 13 bunches per year (Table 4).

The main components of the bunch are its peduncle or rachis, the spikelets and the individual fruits, which are ovoid, weight about 8-15 grams and measure 3-5 cm. The individual fruits count for about 45-65% of the total weight of the bunch. Oil content in the bunch varies between 18% and 32%, according to variety, and type of palm, as explained later. Bunch composition is illustrated in figure 4.

**Table 4.**
**Bunch numbers and weight according to age in an adult commercial planting:**

| Age (years) | Number of bunches (palm/year) | Bunch weight (kg) |
|---|---|---|
| 3 | 19 | 3 |
| 6 | 17 | 11 |
| 9 | 12 | 17 |

### 3.7 Types of fruits

To have a better idea about the different types of fruits, these have to be cut length or crosswise in order to observe the mesocarp and the presence or absence of shell and its thickness. The presence or absence of shell and its thickness is the effect of a single gene without complete dominance. Three types of fruits can be differentiated, and this gives the names to the plants that produce them (Figure 5). When a "dura" palm with a thick shell and thin mesocarp (DD) is crossed with a "pisifera" (dd) palm with no shell, a intermediate palm, named tenera, is the result (Dd), which has a thick mesocarp (more oil) and a thin shell (Figure 6).

From the outside, a ripe oil palm fruit has an exterior layer (exocarp or epidermis) with a smooth and shiny appearance. This surrounds a yellow to orange oily mesocarp (pulp), which in turns surrounds the central seed enveloped in a hard black shell. The seed has as its main components the embryo and the endosperm. The mesocarp oil has been traditionally used as an edible oil and the endosperm oil in numerous industrial uses.

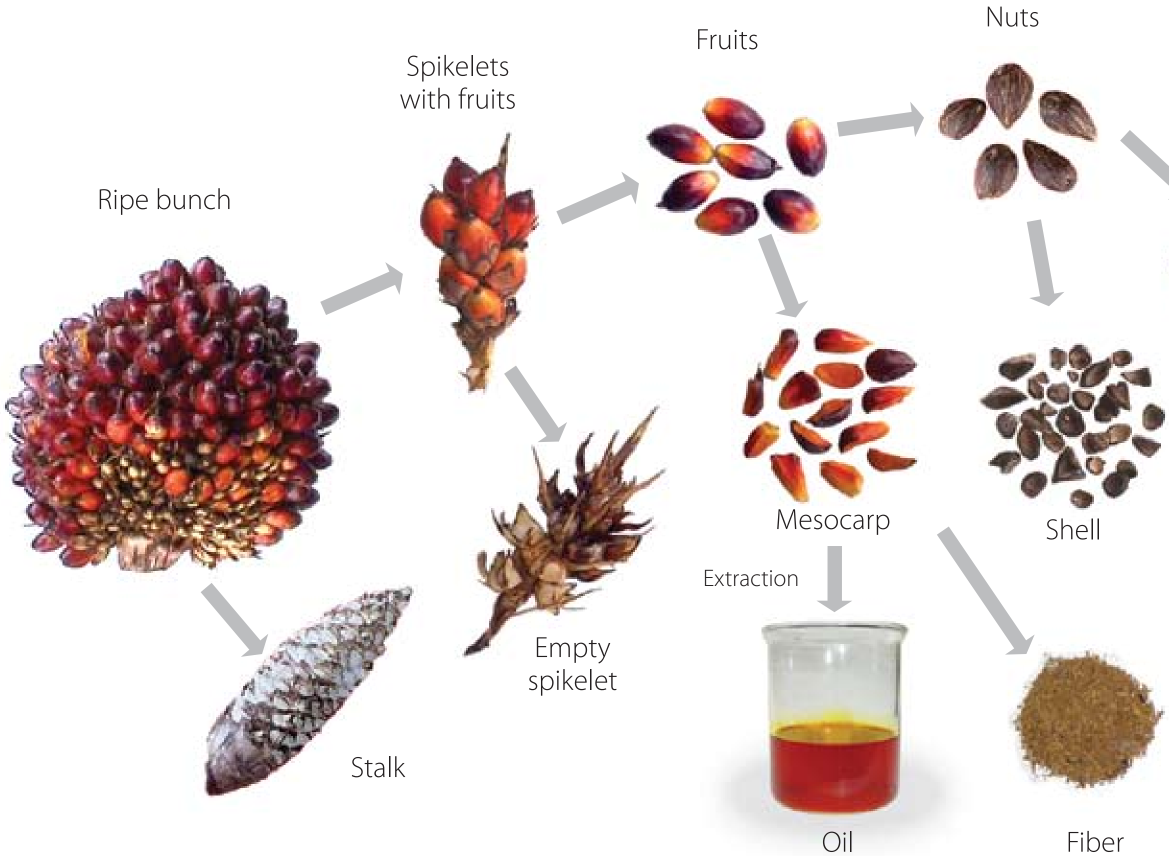


**Figure 4.** Bunch components

Normally every fruit has a single kernel, but up to four can be found in a particular one, which gives rise to seeds that produce up to four seedlings. Table 5 shows the different bunch components in dura and tenera plants. This drawing illustrates why tenera palms are preferred for commercial plantings.

**Table 5.**
**Bunch components in dura and tenera palms (%)**

| Characteristics | Dura | Tenera |
|---|---|---|
| Fruit to bunch[1] | 45-65 | 45-65 |
| Pulp to fruit | 40-95 | 70-85 |
| Kernel to fruit | 10-15 | 5-5 |
| Shell to fruit | 25-55 | 1-30 |
| Oil to mesocarp | 40-55 | 40-55 |
| Industrial extraction | 15-16 | 22-25 |

1 This component is highly variable, even within a particular palm, and depends on pollination efficiency

In commercial plantations "pisifera" palms can be differentiated because they are excessively vigorous and all bunches abort before reaching maturity. However, it is common to name "pisiferas" to almost any unproductive palm, but this is not necessarily true, since there can also be abortive dura or tenera.

Commercial seed production uses pollen from pisiferas (dd) on dura palms (DD) to produce tenera (Dd) palms, known as DxP crosses. The seeds of such crosses will have the general appearance of a dura seed (thick shells and thin mesocarp), but the embryo will originate a tenera palm. Since pisifera palms are normally sterile, such palms are only used as pollen sources (Figure 7).

**Dura:** Thick shell, oil extraction 16 - 18%, normally used as a mother palm to produce commercial varieties.

**Tenera:** The commercial type. Thin shell; oil extraction: 22%- 32% or more.

**Pisifera:** No shell. Palms with this type of fruits normally abort the bunches. A fertile pisifera may contain 40% oil.

**Figure 5.** Fruit types in oil palm

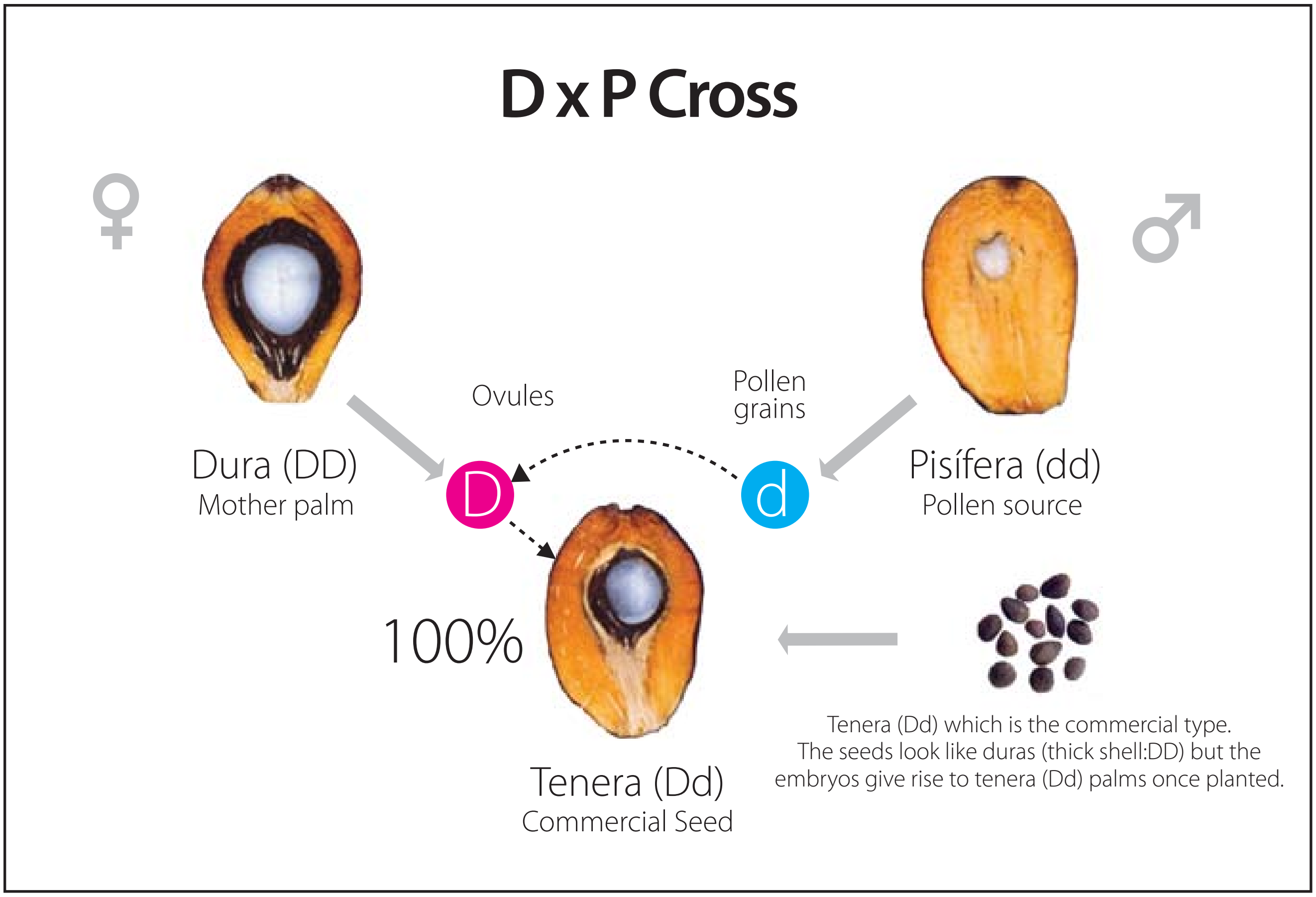


**Figure 6.** The use of the gene for shell thickness to produce DxP commercial oil palm seeds

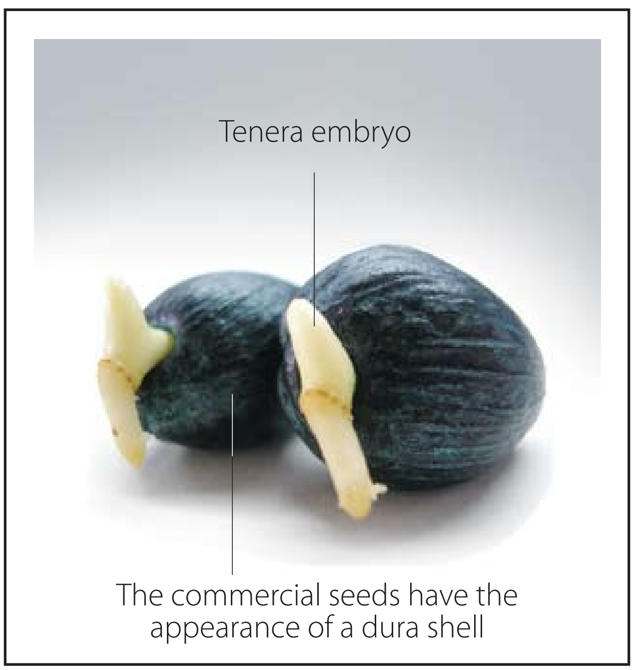


**Figure 7.** Commercial oil palm seeds

## 4. Agro ecological aspects

The oil palm grows and produces very well in the low lands of the humid tropics (18 degrees North and 15 South latitude). The main climatic factors affecting growth and yield are rainfall, temperature and solar radiation.

### 4.1 Rainfall

The oil palm is quite sensitive to soil moisture extremes (drought and moisture saturation) and relative humidity. The best performance of this crop is seen in areas where total annual rainfall is near 1,800 mm; well distributed though the year (about 150 mm/month). Yields can be severely affected in areas with a marked dry season (more than 3 months) or in water saturated soils.

Under these conditions yields may concentrate within a few months. An annual water deficit above 300 mm may reduce potential yields up to 30%. Irrigation has proven to be an attractive commercial option in dry regions in India, Colombia and Central America. Excess of water (above 300 mm/month) in areas without an adequate drainage system may cause severe soil saturation, and negatively affect yields.

### 4.2 Temperature

Temperature is another important climatic factor affecting oil palm yields. The optimum range for growth and best yield lays between 21and 32 °C. Maximum and minimum are also important, and large variations in day mean temperature can be negative, since such changes may induce inflorescence abortion. Long periods with temperatures below 19 °C retard growth, leaf emission rate and even affect pollination negatively

Some new varieties such as Bamenda x Ekona, Tanzania x Ekona and Deli x Ghana perform quite well in the tropic uplands at a altitude up to 1,000 mosl, and in latitudes over 10 degrees, where temperatures drop below 19 °C during several hours during the day in some months of the year.

### 4.3 Solar radiation

Sunlight is necessary for the plants to perform photosynthesis and produce carbohydrates that are used to produce bunches and oil. In general terms, the oil palm needs at least five hours of sunshine a day. Below 350 cal/cm2/day (Langleys) there can be a negative effect on yields. In a shiny day in the tropics radiation levels normally are above 500 Langleys when the sun is shinnying, but clouds, fog and dust in the atmosphere may drastically reduce such levels. Besides this, there is interaction between temperature, carbon dioxide and photosynthetically active radiation, all affecting the ability of the plant to produce carbohydrates.

### 4.4 Topography and soils

In general terms, physical characteristics of the soil are more important than its native fertility, since this last characteristic can be improved through soil amendments and fertilizers.

Even though the oil palm may be grown in a large variety of soils, the best are those with a deep profile (> 1 m), well aerated, with a strong structure, medium textured, a good content of organic matter and preferably with a good natural fertility.

In areas with an extended dry season the best soils are those with a high water holding capacity, but during periods of high rainfall, an adequate drainage system must rapidly evacuate the surplus water. One thing that the grower has to keep in mind all the time is that the root system is a living entity that needs an adequate level of oxygen and water in the soil to grow healthy and perform its functions (Figure 8).

Soils with a gentle slope are preferred, but undulating lands can also be used. If hilly areas are used, there may be the need to construct terraces, which greatly increases the initial planting investment, and for this reason most plantations are established in land with slopes below 12 degrees (21%). Completely flat areas may need special drainage work.

Any oil palm project should start with a general soil survey to determine and quantify limitations and the cost for correction: the need to construct a drainage system, alleviate soil compaction, fertility, and in general any situation that may adversely affect yields in the future.

# 5. Agronomy

The oil palm is a highly efficient oil producing machine (Table 1), but its potential can only be achieved when climate and management are the optimum. There is an extensive scientific literature that supports claims given by expert agronomist to obtain the best from this wonderful plant.

### 5.1 Planting material (seeds)

Seed quality is of paramount importance for any oil palm project. Only seeds from a recognized source should be used, which must be accompanied of both a phytosanitary certificate and another that guaranties its genetic purity. The origin of such seeds is necessarily a reputable breeding program. It is certainly a false economy to obtain "cheap seeds" from an unknown source: the outcome can be disastrous when actual yields will be well below expectations in the original planning investment.

**Figure 8.** Ideal soil characteristics to allow for a vigorous root system growth: deep, well aerated alluvial soils with medium textures (Unknown source).

A breeding program only reproduces varieties resulting from the best combinations between selected mother palms and pollen sources. These palms are selected for their ability to produce oil. Crosses are made artificially (controlled pollination) in order to guarantee genetic purity, so the whole resulting population (variety) will be teneras with a high potential to produce oil (Table 5). The use of seeds from an unknown source may contain a high proportion of seeds that will originate palms of the dura and pisifera type, which will decrease the potential of the plantations to produce oil (Table 5).

Commercial varieties are normally identified with a two-word name: the first indicates the origin of the mother palm, and the second the pollen source. As an example, the variety Deli x Ghana is produced by crossing Deli dura mother palms with a pollen source originated in Ghana. In general, the names used derivate from the country, area, locality or institution that collected and selected the material. Some of the most common varieties available in the international market are the following (most characteristics indicated were observed in the South Pacific of Costa Rica in palms 8 years-old).

**Deli x AVROS:** The mother palms (Deli) originated from seeds planted as ornamentals along an avenue in Sumatra, Indonesia. The source of pollen comes from the breeding program of a private Dutch company based in Indonesia (Algemene Vereniging van Rubberplanters ter Oostkust van Sumatra). This is an excellent variety, but very sensitive to marginal conditions and poor management. The plant is vigorous, with a fast stem growth rate (>70cm/year), large bunches (>15 kg) and fruits (>11g), and with 27 % oil to bunch ratio.

**Deli x Ekona:** The source of pollen originated in Lobe, Cameroon. Stem growth rate is moderate (60-70 cm/year). Other characteristics are medium bunches (<15 kg), rather small fruits (<9 g), high oil to bunch ratio (28%), and it presents moderate tolerance to drought, low temperatures and low solar radiation.

**Deli x Ghana:** The pollen source came from the former “Nigerian Institute for Oil Palm Research, NIFOR”), and was later introduced to the experimental station in Kade, Ghana. Stem growth rate is slow (<60 cm/year), leaves are short, orange petioles, medium size bunches (<15 kg), and fruits (10 g), and an excellent oil to bunch ratio (>28%). Besides, this variety has a good tolerance to low temperatures and solar radiation.

**Deli x La Mé:** The pollen came from Ivory Coast at the former "Institute de Recherches pour les Huiles et Oleagineux" (IRHO). Stem growth rate is slow (<60 cm/year), small bunches (<13 kg), with long thorns particularly toward its tip. Fruitlets are small (<9 g), some of which may develop over the surface. The inflorescence peduncle is rather long. Oil to bunch is about 25%. This variety also shows tolerance to drought in low lands.

**Deli x Nigeria:** The pollen source originated in Nigeria (NIFOR) and was further improved at the experimental station in Kade, Ghana. Stem growth rate is slow (<60 cm/year), medium size bunches (<15 kg), and fruits (10 g), and a high oil content: > 28%. It also shows good tolerance to drought. Within this variety two types of seeds can be obtained: those that will originate palms with black (nigrescens) bunches, or those that will produce both nigrescens and virescens bunches (green when unripe: orange when ripe).

**Deli x Yangambi:** Pollen came from the Democratic Republic of Congo, and from here it was taken to Ivory Coast and other countries. These plants have a vigorous stem growth (>70 cm/year), medium size bunches (<15 kg), large fruitlets (>11 g) and high oil content (27%). Its tolerance to drought is good in low lands.

**Tanzania x Ekona:** This variety has a marked tolerance to low temperatures in uplands and also strives in under dry conditions. Its stem growth rate is moderate (60-70 cm/year), bunches are medium size (<15 kg), fruitlets small (<9 g) and good bunch oil content (26-28 %).

**Bamenda x Ekona:** Excellent tolerance to low temperatures and drought in upper lands. Low stem growth rate (<60 cm/year), medium size bunches (<15 kg) and small fruitlets (< 9 g). Yield for this and the previous cold-tolerant varieties in marginal areas, and under very basic management has been 60 kg/palm/year at 4.5 years of age (12 liters of oil) increasing to 150 kg/palm/year (20-30 l of oil) at six years in upper lands in East Africa.

**Compact varieties:** the main features of the new compact varieties are a slow stem growth rate and short leaves, which makes possible to use higher planting densities (170 palms/ha). The compact palms have given rise to compact clones, which take this idea even further, since some of them can be planted at 200 or more plants/ha. This alone, may increase yield 20-40 % above traditional varieties.

Three-year old Deli x Nigeria palm

### 5.2 Nurseries

Very young seedlings grow slowly and are rather sensitive to adverse environmental conditions, such as excessive solar radiation, weed competition, and the attack of pests and diseases. The nursery phase is an important resource used by growers to give a better care to these young plants. At the end of the nursery phase (12-15 months), only the best palms are taken to the field for definitive planting.

Most growers will favor a two-stage nursery. During the prenursery, which last about 2.5-3 months, the germinated seeds are planted in small plastic bags (16 x 20 cm lay flat and 0.012 cm thickness), which are placed in blocks under shade (40 - 50%) for some time. At the end of the prenursery, the best plants are transferred to larger bags (45 x 50 x 0.015 cm) in a main nursery. Spacing at the stage is very important, and every plant should be given the chance to receive as much sunlight as possible. To achieve this, bags should be arranged in an equilateral triangular pattern (0.9-1.2 m size).

The prenursery phase allows for a better supervision and reduces labor costs and inputs (such as agrochemicals). Besides, at the end of this phase, only the best plants are taken to the main nursery. The use of shade during this phase is of paramount importance, since this is an insurance against the damage caused by excessive sunlight and high temperatures.

At the main nursery, special management should be given in order to produce top quality seedlings. Special attention should be given to the use of an excellent soil to fill the bags and the supply of a reliable amount of water during the whole period. Nevertheless, not all plants will be suitable to be taken to the field, and between 15 and 25 % rouging can be expected.

As an example, for a 1,000 ha project, about 170,600 germinated seeds are needed, assuming 15% rouging. Nursery size should be about 24.5 ha, if a triangular spacing of 1.2 m is used. Good planning is important, so the plants would be ready to be taken to the field (12-15 months old) at the beginning of the rainy season.

Nursery in Coto, Costa Rica (clone material).

### 5.3 Drainage

Yield can be severely reduced if the soil is poorly aerated. Rain intensity can be quite high in some regions, and natural drainage is normally not enough to evacuate the excess. A well planned drainage system takes care of this water and gives the opportunity to the root system to grow and perform its functions. Every project needs a detailed survey to identify the areas where drainage is needed and the type of work required: surface (depressions) or groundwater drainage (water table).

The type of drainage work needed (density, size, type of canals…) is site specific, and depends on soil characteristics, topography and climate.

Bulldozer with a special heavy-duty rack to reduce top soil deterioration while piling forest residues.

In many oil palm plantations, a spacing of 400-500 m is used between the main drains, and 31.2-78.0 m between lateral drains. The general objective of the drainage web is to maintain water table mound at least one meter deep.

Main roads and drains should be done before starting land preparation for planting, so this activity is done in a well-aerated soil. After planting, the drainage work is finished identifying places where superficial waters may still give problems.

### 5.4 Land preparation for planting

Land preparation must be carried out during the dry season and follow a plan in coordination with the nursery activities and actual dates for planting. Land preparation is done having two main principles in mind: 1) causing minimum deterioration to soil physical properties, and 2) keeping the superficial rich-organic matter layer.

The way land preparation is done is site-depending (topography, type of soil, climate, roads, available resources…), and has to consider previous land use: virgin forest, diverse forests, a perennial or seasonal crop, pastures etc.

#### Areas with forests:

When soil structure is weak and rainfall is high throughout the year, land should be prepared without using heavy machinery to avoid soil compaction. The original vegetation is felled and all residues are systematically piled. In order to reduce soil deterioration, trees are cut with chainsaws. Controlled burning can be done, but this eliminates many nutrients and implies the lost of many of the benefits of organic matter. Besides, this operation is not allowed in some places. To preserve more of the organic superficial layer, piling of organic residues is better done using bulldozers, equipped with a special heavy-duty rack that avoids losing and sealing the superficial layers of soil rich in organic matter. If the whole operation is done carefully, the soil physical characteristics and top soil organic matter are preserved, and no additional tillage is normally needed.

#### Cropland and pastures:

The procedure followed depends mostly on soil type and compaction level, type of weeds present and its incidence. Minimum tillage methods are always preferred, but sub soiling may be necessary. Glyfosate herbicide and other broad spectrum products may be used to eliminate the most aggressive weeds.

**Replanting:**

Replanting is normally done when the old palms reach a height that makes harvesting very costly (12-13 m). Abnormal and diseased palms are first eliminated (Ganoderma sp., Ustulina sp., red ring disease etc.). The way these plants are eliminated depends on the disease affecting them. For example, red ring infected palms are poisoned with an herbicide that kills it and at the same time prevents the establishment of the vector of the disease.

## 5.5 Roads

An excellent road network is necessary to allow for supervision and a fast and easy transport of fresh fruit bunches, inputs and byproducts. Besides easy communication with an important public road, the plantation needs a network formed by main and secondary roads which are normally covered with gravel or some sort of material that withstands the traffic.

## 5.6 Planting

The economical success of any oil palm project is largely based on the quality of the nursery palms that are eventually planted in the field, handling of those plants before and during planting and management during the unproductive period. The main selection criteria for nursery plants are based on its bulb diameter (>13 cm), and an open architecture. The use of poor quality or etiolated palms (due to light competition) seriously affects early yields.

Most commonly, oil palms are planted in the field on the corners of an equilateral triangle (9x9 m), obtaining a population of 142 palms per hectare. Higher densities can be used when planting compact varieties and those tolerant to low solar radiation. Some compact clones can be planted at 200, and possibly, more plants/ha.

Planting in terraces

Transportation of nursery plants to the definitive site must be done with great care to avoid unnecessary damage during loading on the trucks, transit and unloading. Planting must be done at the beginning of the rainy season. Deep planting delays early growth and reduces early yields.

Rows are normally oriented North-South for a better use of solar radiation. A legume cover crop should be established during the first year (before planting or soon after) in order to avoid weed competition.

## 5.7 Weed control

For palms of all ages it is important to keep an area free of weeds around the plant: in young palms this avoids the harmful effect of weeds on growth, and for adult palm it facilitates collecting loose fruits. During the first months after planting (6-12 months) this is better done manually, since herbicides may burn the lower leaves, or cause other damage. As the trunk grows in height, and the leaves are higher up, herbicides can be used (both pre and post emergency), but care must be taken not to spray on the leaves. A young oil palm needs all the leaves it produces: this guarantees early and better yields.

Leguminous cover crop

Weed control on the rest of the area (inter lines) can be done manually or by using herbicides. A leguminous cover crop, such as Pueraria phaseoloides, keeps other highly competitive weeds away, and offers many other benefits, such an extra supply of nitrogen, improves soil physical properties, reduces erosion and helps the plant to keep its water balance.

Weed control should be selective, sparing all plants that have been identified as host of predators and parasitoids of known palm pests. These beneficial plants can even be planted along roads, canals and other open areas.

### 5.8 Nutrition

Nutrients are needed for vegetative growth, maintenance and to produce bunches. In order to produce one ton of fresh bunches, an oil palm needs: 1) 4.6 kg of nitrogen, 2) 0.6 kg of phosphorus; 3) 6 kg of potassium and 4) 1.3 kg of magnesium. Consequently, to produce 25 tons of fresh fruits, a total of 115 kg N, 15 kg P, 150 kg K, and 32 kg Mg are needed, and this is without considering fertilizer losses due to environmental reasons or faulty application.

Fertilization represents a high cost in oil palm production, and only second to harvesting. The amount of fertilizer to be applied depends on yield expectations, natural soil fertility and chemical soil properties. Any fertilization program must be based on local experience and experiments, and soil and foliar analysis.

Nutrient demands increase steadily between the second and fifth years in the field, and then stabilize up to the seventh or eighth years. The maximum demand for potassium occurs between the third and fourth years.

Annual fertilization should be splitted particularly for young palms, and in soils with low cation exchange capacity. During the first year after planting, every other month cycles are preferred. For adult plants (5-15 years-old) fertilizer is applied 3-4 times a year, and 2-3 times in older palms.

The amount of fertilizers applied during the second and third years far exceeds the actual amount used for bunch production. However, this early fertilization is used by the plants to accumulate reserves in its different organs, which are essential for early and large yields in the future.

Besides N, P, K and Mg, other nutrients may be needed in some conditions. In tropical America, for example, is common that some elements such as sulfur, boron, zinc and copper are in a deficient condition in some soils. Calcium and chloride may also be applied in some circumstances. Some soils may contain enough of some elements, such as potassium and phosphorus, but these are chemically fixed to soil particles, and are not available to plants.

In young palms, the fertilizer is applied near the plant (on the circle free of weeds around the stem) forming a band or ring. The width of band and its distance from the stem is increased with palm age. For adult palms, the fertilizer is normally broadcast all over the area though it can also be applied part in the circle and part on the inter row, particularly over the piles of leaves cut during harvesting.

### 5.9 Harvesting and bunch transport

Harvesting costs represent near 45% of total costs in adult plantations. This activity is normally initiated when palms are between 23 and 36 months. Precocity and early yields depend on environmental conditions, the variety, the quality of the nursery plants, care during planting, and early management.

The very first bunches produced are small and contain no much oil, and they are normally not harvested. About a week before the first commercial harvesting, the palms are cleaned (sanitary pruning) of old dead leaves and bunches. No green leaves should be cut, since a young palm needs all of them. During early harvesting rounds it is recommended to "steal" the bunches, which means to cut the ripe bunch without cutting any leaf. This practice may be done until the bunches are located to a height of one meter over the soil surface. Bunches may be cut using a narrow chisel (5-8 cm width), with a metal handle about 1.2 m long, or a small Malayan knife (sickle-shaped) attached to a short aluminum rod. The intention is cut as few green leaves as possible.

Bunch weight increases with palm age, from about 2.5 kg at the beginning (2-3 years after planning), to 25 or more kilograms in adult palms. However, the number of bunches produced per palm decreases with its age. An adult palm may produce 8-13 bunches per year, which represents about 140-175 kg of FFB (fresh fruit bunches), which will generate 30-38 kilograms of red (mesocarp) oil at the extraction mill.

The maximum potential in terms of FFB production is normally reached in commercial plantations when the palms are between four and eight years old. During this period, yields can be between 15 and 40 tons of FFB per year, which represents 3.3-8.8 tons of crude palm oil/ha (considering 22% extraction at the mill. The reasons for such differences have to be found on climate, soils, agronomic management, and of course, the variety used.

Harvesting is somehow tricky in the sense that bunches accumulate most of its oil during a relatively short period (a few days) of time of its development. If the bunch is cut too early (unripe) it will contain less oil than its potential. If cut too late, the oil will be partially deteriorated (free fatty acid accumulation). The optimum degree of ripeness is judged by the harvester by considering bunch color, texture, the change in color, and the presence of loose fruits. Ripen fruitlets become soft, and change from a black coloration to shiny brown and finally to an opaque reddish-brown appearance at the tip and orange-reddish on the medium section. The period needed to reach maturity varies according to palm age, the variety and environmental conditions, but normally takes between 5.5 and six months from the period of anthesis (pollination). As a general rule, bunches are harvested in young palms when 10 or more loose fruits are detected. For adult palms, the number of loose fruits is reduced to five.

In order to collect the highest possible proportion of bunches with the optimum degree of ripeness; harvesting cycles have to be relatively short: every 8-15 days, depending on palm age and time of the year (bunch density). During the first 5-6 years, harvesting is done with a metal chisel (14 cm width or less), welded to a metal hollow rod or attached to a wood pole (1-3 m long) (Figure 9). In adult palms, harvesting is done using the so-called Malaysian knifes (sickle-shaped) attached to hollow aluminum poles, which are light and very flexible. The length of the aluminum pole is increased with palm height. A worker may cut 100-300 large bunches (10-25 kg) per day on an adult planting, or 400-1,000 small ones (3-8 kg) in a young plot. Efficiency depends on the ability of the worker and bunch density.

Special care must be taken during bunch collection within the plantation and transportation to the


**Figure 9.** Harvesting of young palms using a chisel (a) and a Malayan knife (b) on adult palms

mill: bunches have to be handled with care to minimize physical damage, and they have to be taken to the mill as soon as possible. Once at the mill, processing should be done the same day to reduce oil acidification.

In general terms, 550-650 kg of FFB occupy a cubic meter. Carrying the bunches within the harvesting lots can be done by men (using wheelbarrows, bikes, sacks…), but its efficiency is normally low: 1.5-2 tons/day. The use of mules increases efficiency considerably, carrying the bunches directly in special devices on their backs (walking distance should be less than 250 m) or hauling carts with about half a ton of FFB (Figure 10). A couple of oxes may haul a two-axes cart with up to a ton of FFB. These systems work well with internal roads built every 250-500 meters. Buffalos can be even more efficient hauling bunches.

Motorized equipment can also be used (about 45 HP) within the plantation, but there is a risk to cause soil compaction, unless special tires are used, which can also be used for buffalos or ox carts. These equipments make carry 0-5-3 tons of FFB. Once the fruit from inside the harvesting lot is taken to a particular place, larger trucks must transport it to the mill. In general terms, the extraction mill should be located within 20 km of the place where the bunches are harvested to reduce transporting costs.

**Figure 10**. Bunch transportation within the plantation

### 5.10 Pruning

A so-called sanitary pruning is done just before the first harvesting cycle. This job is done cutting all severely damaged and old dried leaves, and rotten bunches and inflorescences as well. It is of primary importance to leave as many green leaves on the plant as possible: this is a key aspect to consider for young palms.

Leaves subtending ripe bunches are cut during the regular harvesting cycles, but other old leaves with no bunches (that produced males or aborted) accumulate with time on the palms. In order to do a better use of labor, these leaves are normally cut once a year during the low peak of production. In general terms, 36-40 leaves are left on an adult palm after the pruning cycle: all dry, bent leaves are cut, as well as those green ones not bearing bunches

### 5.11 Phytosanitary aspects

A given commercial oil palm plantation may confront important phytosanitary problems that may seriously reduce the expected yields and even threat the whole investment. In several countries in Africa, Fusarium wilt (*Fusarium oxysporum* f. sp. *elaeidis*) is considered an important threat to oil palm development.

This pathogen was apparently brought to America as a contaminant of some vegetable imports (leguminous seeds used as cover crops) or in infected oil palm seeds. By the time being the disease seems to be confined to small foci in Brazil and Ecuador, but this experience reminds us the importance to look with caution the importation of seeds from areas in Africa contaminated with this pathogen.

The fungus *Ganoderma* spp., is a serious threat for oil palm cultivation in Southeast Asia, but is considered a pathogen of secondary importance in America.

Besides diseases, there are many pests that sometimes may cause severe economical damage, particularly defoliators that make very important to keep a continuous monitoring of the plantation.

In tropical America, there are also important phytosanitary problems, among which the red ring disease caused by the nematode *Bursaphelenchus* (*Rhadinaphelenchus cocophilus*) is probably the most important. The nematode is transmitted by the American palm weevil (*Rhynchophorus palmarum*) and so control is normally directed against it.

Other diseases are less common (but can be of primary importance for particular plantations). Among these are the foliar lesions caused by *Pestalotiopsis* spp., sudden wither (*Phytomonas* sp.), corky basal rot (*Ustulina deusta*), wet basal rot (possibly *Erwinia* sp.), and upper stem rot (possibly *Phellinus* sp., but can be a disorder associated with stress in some stress-susceptible varieties).

Insect larva: pest of the oil palm

Rotting and dryness of young spears, generally accompanied with yellowing of young leaves are with no doubt of the main concern for oil palm producers in tropical America. No primary causal agent has been found for these disorders despite many years of research, and so a lot of confusion has been generated in the literature when different local names have been given to what are probably variations of the same disorder caused by differences in environmental conditions.

Most of these spear rots are no diseases in the traditional meaning, but they can be better explained and eventually managed if they are considered as a decline of the population of plants associated with adverse environmental and managing practices that cause progressive stress on them. This approach has been used in several commercial plantations with very good results to recover plants and improve productivity. The most relevant action taken has been improving general agronomy (soil aeration, balanced fertilization…)

# 6. Yield potential

Palms begin producing harvestable bunches 2-3 years after planting according to management and environmental conditions. From there on, yields increase progressively with age and stabilizes 4-6 years later. Yields show an annual variation and after 12-15 years start decreasing. Table 6 shows a common yield curve under favorable environmental conditions and good management:

**Table 6.**
**Commercial fresh fruit bunch (FFB) yield according to age in oil palm**

| Age (years) | Fresh fruit bunches fresca (t/ha/year) | Oil (t/ha/year) |
|---|---|---|
| 3 | 7.9 | 1.6 |
| 4 | 16.5 | 3.6 |
| 5 | 23.6 | 5.4 |
| 6 | 25.8 | 6.0 |
| 7-18 | 28.0 | 6.7 |
| 19 | 28.0 | 6.6 |
| 20 | 28.0 | 6.6 |
| 21 | 27.0 | 6.6 |
| 22 | 26.2 | 6.1 |
| 23 | 25.9 | 5.9 |
| 24 | 24.7 | 5.5 |
| 25 | 23.5 | 5.2 |

Even though the former is a rather common yield, some harvesting lots may behave differently and show the real potential of modern varieties, which is close to 45 t of FFB/ha/year. The gap between actual commercial yields and potential yields is the result of using poor quality planting material, poor management and under optimum environmental conditions (soils, climate). In regions with a severe water deficit, low temperatures or low solar radiation, yields can be quite low.

# 7. Industrialization

Oil in the fruit mesocarp and kernel is extracted in mills normally located near the plantation. The capacity of a given mill is expressed in tones of FFB processed per hour, which may vary between 3 MT FFB/day and 120 MT FFB/Day. The quality of the oil obtained depends mainly on its acidity, which normally should be less than 3%. The uses of palm oil are numerous, both in human nutrition and the industry of soaps, cosmetics, paints…The industrial process is summarized below:

### 7.7 Weighing and bunch reception

FFB arrive to the mill in trucks or trailers. Upon arrival and after unloading the trucks pass through a weight bridge were net weight is calculated and recorded on a computer together with additional information such as fruit origin, and grade. The fruit bunches are unloaded in large metal hoppers, normally mounted 5 to 6 mtrs above the sterilization section.

### 7.8 Sterilization

This is the first step during oil extraction and it has three objectives: to kill all microorganisms, to inactivate the enzymes (lipases) that cause undesirable oil acidity, and to accelerate the natural process of fruit detachment from the spikelets.

Bunches are moved from the hoppers to horizontal sterilizers where they are steam-sterilized with 3.1 bar steam. The process requires that three factors be controlled: temperature, time of exposure to temperature, and steam pressure. Depending on mill capacity, the FFB are placed for sterilization in “cages” or “baskets” of 2-10 tones capacity. These cages are moved from the hoppers to the “sterilizing area” on a fixed railroad system.

Obtaining red oil (press system) without cracking the nuts

### 7.9 Threshing

The mass of hot bunches and loose fruits coming from the sterilizers is fed into a threshing drum, which rotates and make the bunches tumble and separates the loose fruits which fall out. The capacity of the threshing drum is variable: 5-45 t/hour.

Horizontal sterilizers

### 7.10 Digestion and pressing

The fruits already separated from the empty bunches are further cooked with steam and stirred with rotating arms in the digesters with the objective of loosening the pericarp form the nuts and breaking the oil cells. Presses extract the oil from the conditioned fruits by means of high pressure, with is adjusted to provide minimum damage to nuts (5-8% broken nuts) maximum oil extraction.

### 7.11 Clarification

The objective of this process is to separate the oil from water and diverse impurities, which can be done using a combination of different techniques such as, static clarification , high speed centrifuges, decanter, and sometimes vacuum driers. At the end of this process the oil has been dehydrated (0.15% water) and will contain approximately 0.03 % solid materials.

### 7.12 Depericarper Station and Kernel extraction

This is a specialized section within the mill with the objective of recovering the kernels from the mass of fibers and nuts coming from the presses. The press "cake" is broken in a conveyor and the nuts are separated by means of a pneumatic column. The separated nuts are cracked, and the resulting kernels and shells are separated in a combination of pneumatic columns, hydrociclones, or clay baths. The recovered nuts are dried and stored in a silo for sale or for further processing. Before cracking, the nuts are stored in heated silos to shrink the kernel away from the shell.

### 7.13 Power supply

An oil palm mill can be self-sufficient in terms of energy. Steam is produced in boilers fed with by-products of the same process, mainly fiber from the presses and shells from the nuts. Electricity is normally obtained from steam turbines and diesel generators.

### 7.14 Kernel oil extraction

Dried kernels are ground and feed to the presses to obtain kernel oil and a "cake" that has many uses, particularly as animal feed.


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# 8. Economical aspects

Business projects in oil palm can be separated at three levels: 1) FFB production, 2) production of crude palm oil (CPO) and 3) refinery and production of terminated products. Most large companies will have two or all these levels forming a vertically integrated business.

The first level (field) is occupied by growers that sell its product to private mills through different commercial contracts. At this level, investment, risks and profits per hectare planted are less. Without considering land, a grower may need US $1,500 to $ 2,500 as an initial investment per hectare. Once in production, he will need $25 - $35 to produce a ton of FFB. His profit/ha/year will be situated between $500 and $800.

The second level is related to the production and selling of the crude palm oil, where investment, risks and profits are normally larger that just selling FFB. The cost to establish an extraction mill depends on its capacity to process FFB (tons/hour). As an example, a 1,000 ha plantation will need a mill with a 8-10 ton/hour capacity. One ton capacity costs about $250,000; which means that the initial investment is 2-2.5 million dollars. The cost to extract a ton of crude palm oil is near $50, and profits can be situated around $ 125 per ton of oil produced.

Finally, at the third level are placed those investors that produce the final products with added-value. Investments, risks and profits are large on this end.



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