The Oil Palm: Progress Through Plant Breeding in Malaysia*

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In the past 20 years the oil palm has developed from being just one of a number of plantation crops into a major supplier of vegetable oils, taking second place after soya and overtaking such crops as groundnut, sunflower, olive and coconut. Whereas in 1970 world palm oil production was estimated to be less than two million tonnes, it has now passed the five million tonne mark. A major share of this increase has come from an almost explosive development of oil palm cultivation in Malaysia, where in ten years production has increased more than fivefold to well over 2.5 million tonnes and is still rising.

Other major producing countries and their shares of world output are: Nigeria (14%); Indonesia (14%); Ivory Coast (3%); and Zaire (2%); while oil palm developments are taking place in many tropical countries with suitable climates, including Brazil, Colombia, Ecuador, Panama, Costa Rica, Papua New Guinea, the Solomon Islands, New Britain, Thailand and the Philippines.

The African oil palm (*Elaeis guineensis* Jacq.) occurs naturally in the tropical rainforest belt of West Africa within 10° of the equator. Its natural habitat is probably swamps and river banks, but since palm oil has been used in West Africa for many centuries it is now widely distributed in the area. A related species, *E. oleifera,* is found in South and Central America and in spite of their evolution on distant continents both species can be hybridised and produce fertile offspring. Oil yield of *E. oleifera* is much lower than that of *E. guineensis.*

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The fruit and its oils

The oil palm is a typical palm with a single growing point; it bears separate series of male and female inflorescences that are formed in sequence in the axils of fronds. The palm is therefore an obligate cross pollinator. After pollination the female inflorescences develop into fruit bunches which weigh from 1kg to over 50kg and which consist of small ovoid fruits 2–5 cm in length. When ripe there will be 50–100 purple red fruits per bunch in young palms and up to 3000 fruits per bunch in old ones. The oil is found in the fruit flesh surrounding a hard lignified shell which covers a round white kernel containing kernel oil.

Palm oil is a fruit coat fat and it is commercially fractionated into olein and stearin. The traditional uses are in margarines, shortenings or compound cooking fats, confectionery, ice-cream, non-dairy creams, and also for frying. Non-food uses include soaps and oleochemicals, while recent investigations suggest that the fatty acid esters may have some potential as a fuel for internal combustion engines.

The kernel oil has a different composition to the fruit coat oil and (together with oils from coconut and the babassu nut) is classified as a lauric oil. It is regarded as a high quality oil for food use and in the manufacture of good quality soaps. Lauric oils are the only natural source of the short-chain saturated fatty acids which are important in the chemical industry.

Early breeding and selection

Oil palm breeding and selection is closely linked with the origin and development of the oil palm as a plantation crop. From the time of the industrial revolution, trade in palm oil collected from village groves in West Africa gradually gained in importance; later, organised collection developed to ensure regular supplies (Hartley, 1977). The development of the oil palm as a plantation crop, however, first took place in Sumatra, where in the 1880s trees were planted as avenue palms on tobacco estates. These palms originated from four botanical specimens introduced into the famous Bogor Botanical Garden in Java in 1848.

A visiting Belgian, M. Halet, who was familiar with oil palms in Zaire, was impressed by the high productivity of these avenue palms, and with seeds collected from them he started the first oil palm estate in Sumatra in about 1911. The potential of the crop was soon realised, and by the 1920s several estates had been established and a new plantation crop was born. Almost immediately, selection programmes were started to identify high-yielding palms to serve as parent material for seed production. Controlled crosses for seed production were facilitated by the large number of fruits resulting from single pollinations of individual bunches.

The starting material – a population referred to as Deli Dura, after Deli (the area in Sumatra) and Dura (a fruit type with relatively thick shell), proved to be fortunate. The quality of the fruits was immediately superior to most Dura fruits found in West Africa.

Early selection work concentrated on increasing the number of bunches and the amount of oil per bunch (the latter is determined by various easily measured bunch and fruit components – i.e., the ratios of fruits: bunch; mesocarp: fruit; oil: mesocarp; kernel: fruit; and oil: kernel). Large numbers of palms were assessed using these ratios and then selected palms were crossed for seed production. Progeny trials were then planted for the next generation selection in several breeding programmes in Sumatra and Malaysia. This form of family and individual palm selection continued for two or three generations until the 1950s (Corley, 1982).

After the first generation of selection, yield advances of over 20% were realised, although they fell to 10–12% in subsequent generations (Corley *et. al.*, 1976). In the Malaysian environment this meant that oil yield increased from an average of some 2.5t/ha/yr in the 1920s to about 4.5t/ha/yr in material produced in the 1950s. By this time genetic variation in breeding populations of Deli Dura appeared to have become a limiting factor as a result of largely unconscious inbreeding of material with an obviously narrow base – the four Bogor palms. Genetic studies indicated reduced levels of additive genetic variation for most production factors (Hardon, 1970).

Recent progress

In the 1950s breeding took a fundamental change of direction. For some time it had been known that a fruit type known as Tenera, with a thin shell, occurred in West Africa. Because of their reduced shell thickness Teneras have correspondingly more oil-bearing mesocarp than Duras (60%–85% per fruit as against 45%–65%). The use of Teneras in West African breeding programmes, however, resulted in progeny with a high proportion of virtually sterile palms which only occasionally produced a few fruits. These fruits are devoid of shells and are referred to as Pisiferas.

Studies have indicated that there is single-gene inheritance of shell thickness, with the Duras being homozygous for a thick shell, Pisiferas homozygous for the absence of shell, and Teneras being heterozygous (1). Hence, when Teneras are self-fertilised segregation occurs in the three fruit types (1:2:1) but when Duras are crossed with Pisiferas all the offspring are Teneras. However, Pisiferas are usually female sterile and therefore cannot be selected on their own performance, which makes progeny testing necessary.

The use of this single gene has allowed the percentage of oil to bunch to be increased from 16%–18% in Duras to 20%–25% in Teneras, raising the production of oil per hectare by at least 20%. Breeding programmes were accordingly modified from simple selection for Duras to selection for Duras and Pisiferas which, when combined, gave high-yielding Teneras. An added advantage was that the introduction of unrelated Tenera crosses added much needed genetic variation to breeding populations.

Breeding programmes in West Africa – notably at the Institut de la Recherche sur Huiles et Oléagineux (IRHO) in the Ivory Coast – adopted a modified form of recurrent reciprocal selection, exploiting a certain amount of apparent hybrid vigour in inter-population crosses between Deli Duras and Pisiferas of West African origin (4). In Malaysia Deli Duras lines were crossed with new Tenera material to create new, genetically more variable populations with an emphasis on exploiting additive variation (Corley *et. al.*, 1976 and Hardon *et. al.*,).

Crop physiology studies have increased the understanding of inter-palm competition. Harvest-index (HI), which is the ratio of dry matter in the harvested product to the total dry matter per palm, can be determined by non-destructive measurements and has become an important selection character (Hardon *et. al.*, 1972). The object is to select palms that maintain a high HI under a high planting density; by improving light interception this makes good use of the potential of the environment. An added advantage of a high HI is relatively less vigorous growth and height increment.

Progress in the selection of oil palms is a relatively slow process, and results from selection for HI combined with bunch yield are only now becoming apparent. Nevertheless, results have been worthwhile, for the change-over from Duras to Teneras and the use of progeny tested Pisiferas have increased oil yields to a level where six tonnes per hectare per year is not uncommon in Malaysia. What is more, increased attention to genetic variation and the development of new breeding populations has raised expectations for further progress.

New developments

Until recently, oil palms could only be multiplied through seeds, for they do not produce suckers nor can they be grafted or multiplied by cuttings. However, a major breakthrough was made using tissue culture techniques in the late 1970s in England and France (Jones, 1983). It was found to be possible to grow oil palm tissues on artificial growth media and the tissue could be induced to form embroids and subsequently plantlets.

The first artificially produced clones were planted and laboratory techniques are now being adapted to allow large-scale production of clonal planting material. It is expected that by 1985 the first clonal planting material will become available for commercial planting in Malaysia. Conservative estimates based on present experimental field trials suggest that such plantings may well out-yield present-day Teneras by around 30%.

Apart from an increase in bunch yield, a major improvement is expected in the oil content per bunch, and since individual palms can now be reproduced, simultaneous selection for a larger number of characters becomes possible. Apart from oil yield, in the selection of clonal mother palms attention is given to characters such as reduced height, high harvest index, yield stability and adaptation to specific environments. Extensive research is also in progress to study variation in oil composition in order to improve oil quality through selection.

Tissue culture has increased interest in the hybrids of *E. guineensis* x *E. oleifera*: the latter produces a high quality unsaturated oil, although the yield of oil is low. The oil yield of the F_1 hybrid is intermediate between both parental species, in back crosses to *E. guineensis*, however, occasional palms are found that combine good yield (from *E. guineensis*) with improved oil quality and reduced height increment (from *E. oleifera*): such palms can now be multiplied clonally.

Critical to breeding of perennial crops are plenty of land and continuity over time: both conditions have been met during the past 30 years in Malaysia, and the results are obvious. There is now a considerable amount of information on the genetics of most yield components and vegetative growth characteristics, on population structure and on the crop's physiology; in fact, oil palm is probably better researched than most other perennial crops, including those of more temperate climates. Starting from an almost accidental breeding population with a very narrow base, increased attention is now being directed at widening gene pools through systematic collection in centres of diversity in West Africa (Rajanaidu *et. al.* 1981).

Parallel to the breeding effort, research on the crop's agronomy and on pest and disease control have progressed (Corley *et. al.*, 1976). It has now been suggested by Corley (1982) that considerable increase in crop dry matter production are still possible, using palms bred to maintain a reasonably high harvest index at high populations. At the moment, current plants tend to concentrate on vegetative growth under the stress encountered at high densities. If this problem can be overcome, however, the physiological potential of the crop may well be in the region of 12–14 tonnes of oil per hectare per year.

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