

CHAPTER 2

LITERATURE REVIEW

2.1 Origin and Biology of Oil Palm

2.1.1 Origin and Distribution

The oil palm, *Elaeis guineensis* Jacq. is widely grown commercially in the Southeast Asia, Africa, Equatorial America and South Pacific. The specific name *guineensis* shows that the first specimen described was collected in Guinea, West Africa. The oil palm is originated in West Africa (Zeven, 1967). Zeven (1967) considered the main oil palm belt to begin in Guinea spreading south through Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Zaire and Angola. From Central West Africa, the oil palm spreads through Zaire, Tanzania, Mozambique and to Madagascar. He believed that the spread was due to man. Its introduction to Southeast Asia has become one of the most important economic crops especially for Malaysia and Indonesia. Oil palm was endemic to West Africa and it came to the East via Mauritius island in 1848, where four seedlings were planted in Indonesia and then went to Singapore Botanical Gardens in 1870 and then to the Malaya in 1875 (Whitmore, 1973). The four seedlings were planted in the Botanical Gardens, Bogor in Java in 1848 and later distributed to Sumatera between the years 1853 to 1856. The oil palm planted in

Deli, Sumatera gave rise to the Deli *dura* palms. The oil palms in Indonesia and Malaya is derived from these four seedlings and their offsprings. In Malaya, palms of Deli origin were planted in Rantau Panjang, Kuala Selangor around 1912. The planting of 1912 came into bearing in 1917, and seedlings from these palms were planted in Tennamaran and Elmina Estates. By 1925, Malaya had 3438 hectares of oil palm and the oil palm industry gained full momentum only after 1930. By 1940, the area under oil palm in Malaya reached 31 000 hectares (Latiff, 2000).

2.1.2 Taxonomy and Classification

The oil palm belongs to the genus *Elaeis* under the family of Arecaceae. The family of palms, the Arecaceae formerly known as the Palmae, has always formed a distinct group of plants among the monocotyledons. It is considered as old as any other family of flowering plants with fossils discovered in Cretaceous rocks dating back some million years (Purseglove, 1972). The Arecaceae are placed under the order Arecales. The oil palm, *Elaeis guineensis* Jacq. is grouped with *Cocos*, the coconut in the subfamily Coccoideae.

The genus *Elaeis* is derived from the Greek word *elaion* which means oil. The specific name *guineensis* shows that the first specimen of oil palm described was collected in Guinea, West Africa and was described by Jacquin in 1763. There are currently three accepted species of *Elaeis*. These are *Elaeis guineensis*, the African palm oil, *Elaeis oleifera*, the American palm oil and *Elaeis odora* (Wessel-Boer, 1965) which is not cultivated and little is known about it.

The keys to distinguish between *Elaeis guineensis* and *Elaeis oleifera* are presented in Table 1 below:

Table 1: Keys to Distinguish between *Elaeis guineensis* and *Elaeis oleifera*

Keys	<i>Elaeis guineensis</i>	<i>Elaeis oleifera</i>
Trunk	Tall trunk	Short, erect, procumbent trunk
Leaflet Arrangements	Pinnate-leaved, arranged in upper and lower on each side of rachis	Leaflets lie in one-plane, have no basal swellings
Female Inflorescence	At anthesis, the spathe of the female flower remains uncovered	Persistent spathe, ripe bunches are covered by fibrious spathe

2.1.3 Habitat and Growing Environment

In its natural habitat, *E.guineensis* occurs in riverine forests, often associated with *Raphia* (Chevalier, 1934) or in fresh water swamp (Waterston, 1953). Its natural habitat is in the poorly drained and flooded areas in Central America and North Colombia (de Blank, 1952). The biggest area of semi-wild *E.guineensis* groves in the lowland regions of Western and Central Africa lies between 10°N and 10°S, which have a marked dry season lasting up to four to six months. It is generally known that *Elaeis* thrives well between a mean minimum temperature of 20°C to 23°C and a mean maximum temperature of 28°C to 32°C which normally occurs in tropical countries. In Malaysia, oil palm can be grown on a wide range of soils such as coastal alluvial clay in Peninsular Malaysia and the riverine and coastal alluviums in Sabah (Latiff, 2000).

2.1.4 Morphology and Growth

Elaeis guineensis is a large, pinnate-leaved palm having a solitary columnar stem with short internodes. There are short spines on the leaf petiole and within the fruit bunch. The leaves are separate upper and lower ranks of leaflets on the rachis. Oil palm is monoecious, with male and female inflorescences occur separately on the same plant developing in the axils of the leaves. The fruits are borne on a large, compact bunch. The fruit pulp which provides palm oil surrounds a nut, the shell of which encloses the palm kernel.

The oil palm is unbranched tree which can grow up to 20–30 m tall. For several years the trunk is completely covered by frond bases which start to fall off when the palm reaches more than three years old when the apex has reached its full diameter in the form of inverted cone, after which internodal elongation takes place. The stem width diameter of 22 cm to 75 cm, bears a crown of fronds and inflorescences derived from a single meristem located in the stem apex. The crown consists of 40-50 pinnate leaves arranged in two spirals. Each leaf remains enclosed in terminal cone for about two years before developing into a central spear (Purseglove, 1988).

Early growth of the seedling is the formation of a wide stem base with a single terminal meristem. During the first few weeks of growth, the seedling is entirely dependent on the supply of stored material from the endosperm. Alang et al. (1988) found out that the endosperm contained 47% fat and 36% galactomannan, a carbohydrate which the seedling utilized before the fat. A trunk is not visible until the palm is three years old

when the apex has reached its full diameter in the form of an inverted cone. The base of the trunk is about 60 cm in diameter and the trunk about 40 cm in diameter. The rate of trunk extension is about 25 cm to 50 cm per year. All mature palms have a solitary columnar stem with persistent frond bases. The stem supports a crown of fronds (Corley and Gray, 1976)

The frond consists of leaflets, each with a lamina and midrib, a central rachis to which the leaflets are attached, a petiole and a frond sheath. The leaflets are long, ranging from 55 cm to 65 cm and narrow with a width from 2.5 cm to 4.0 cm. The leaflets are arranged alternately in two planes. The crown consists of 40 to 50 opened fronds and the central cone a further 40 to 50 fronds in various stages of developments. The number of fronds produced annually increases to 30 to 40 at 3 to 4 years old and later declines to 18 to 25 fronds (Corley and Gray, 1976).

Floral initiation in mature palm starts at 33-34 months before anthesis. Each flower primordium is a potential producer of male and female organs but one or the other remains rudimentary to produce male or female inflorescences. Both male and female inflorescences are borne in frond axil. Hermaphrodite inflorescences bearing both male and female structures are occasionally produced especially during the early years of production. Male and female inflorescences normally occur in different cycle, reducing the chance of self-pollination (Turner and Gillbank, 1982). At anthesis, the male and female inflorescences have the same aniseed scent. The scent attracts numerous insects

such as the weevil, *Eleidobious kamerunicus*. This species of weevil which was imported to Malaysia from Cameroon, plays a dominant role in oil palm pollination (Syed, 1979).

Fruit bunches ripen five to six months after pollination. The number of fruits per bunch varies with age, normally 1000 – 1500 fruits and 10 – 60 kg in bunch weight. Fruit size and shape vary according to fruit position in the bunch. The outer fruits are normally fully formed because of ample space for their development as compared to the inner fruits, which tend to be somewhat flattened, smaller and less pigmented. The oil palm fruit is a sessile drupe, spherical to ovoid or elongated in shape, measuring about 2 cm to 5 cm in length and average weight per fruit ranges 3 g to 40 g (Turner and Gillbank, 1982)

The exocarp of the fruit is smooth and shiny, has a range of colours when ripen depending on the pigmentation namely the *nigrescens* (reddish black), *virescens* (greenish orange) and *albescens* (pale yellow). The mesocarp is the most important part of the fruit for oil production. The shell to fruit (S/F) ratio depends on the fruit form with *dura* 35-65%, *tenera* 60-96% and *pisifera* is shell-less (Turner and Gillbank, 1982). The endocarp or the shell is a hard stony layer making up 1-55% of the fruit by weight and ranges from 0.5 to 8 mm in thickness. Inside the endocarp is the kernel covered by dark brown testa, comprising 5 to 20% by weight. It is also rich in oil, known as palm kernel oil, a source of lauric acids (Turner and Gillbank, 1982).

The oil palm starts bearing bunches at 30 to 36 months after field planting and involves two to three harvesting rounds per month. The bunch weight increases with age

from 5 to 7 kg for three to four years old palm to 20 kg or more for 15-year old palm. The oil palm economic life span is 20 to 25 years, bearing 5 to 20 bunches per year (Turner and Gillbank, 1982).

2.1.5 Inheritance of Fruit Characteristics

Based on the shell thickness, oil palms can be classified into three fruit forms that are *dura* (D), *tenera* (T) and *pisifera* (P). The first step of genetic improvement in oil palm was based on the discovery of shell thickness inheritance where homozygous dominant, thick shelled *dura* (sh^+sh^+) was crossed with homozygous recessive shell-less, *pisifera* (sh^-sh^-) producing a 100% heterozygous, *tenera* (sh^+sh^-) (Beirnaert and Vanderweyen, 1941). *Dura* fruit form was described having a thick shell (2-8 mm) with mesocarp content 35 – 65% and has no fibre ring. *Pisifera* fruit form was shell-less and female sterile with mesocarp content of 92 - 97%. The *tenera* has thin shell (0.5-4 mm) with mesocarp content of 60 - 90% and a fibre ring (Hartley, 1988). The shell thickness gene has major effects on bunch composition, with *tenera* having about 30% more mesocarp and hence 30% greater oil content in bunches than *duras* (Corley and Tinker, 2003).

The production of oil palm planting material (D×P) through hybridization of *dura* (maternal) and *pisifera* (paternal) palm was sparked after the discovery of shell gene (*dura*, *tenera* and *pisifera*) by Beirnaert and Vanderweyen (1941) in Congo. The D×P known as *tenera* was used as planting material in Malaysia. The selection of thin-shelled *tenera* is due to high oil-bearing content in *tenera* fruit mesocarp (75-85%) than *duras* (20-65%) (Kushairi and Rajanaidu, 2000).

Recently, molecular markers have been identified to distinguish between *dura*, *tenera* and *pisifera* at the preliminary level (Rajinder et al., 2013). Rajinder et al. (2007) reported an effective method to develop simple sequence repeat (SSR) markers where a set of 12 informative SSR markers was identified and found suitable for fingerprinting the oil palm tissue culture. Wong et al. (2015) tested SSR markers to genotype oil palm breeding and commercial planting materials of restricted and mixed parentage from Advanced Agriecological Research Sdn Bhd (AAR) and the results obtained from screening 33 palms using a selected set of 17 highly polymorphic and informative SSR obtained from an initial set of 23 SSR showed that clones, crosses and sibs within crosses could be separated by DNA fingerprints.

Rajinder et al. (2014) also identified the *virescens* (VIR) gene which controls fruit exocarp colour and the indicator of ripeness. Five independent mutant alleles of VIR were identified in over 400 accessions from sub-Saharan Africa that account for the dominant negative *virescens* phenotype. The identification of VIR will allow selection of the trait at the seed or early nursery stages, 3-6 years before fruits are produced, greatly advancing introgression into elite breeding material.

Babu et al. (2017) also identified shell specific cleaved amplified polymorphic site (CAPS) marker for differentiation of oil palm fruit type which produced two alleles (280 and 250 bp) in *dura* genotypes, three alleles (550, 280 and 250 bp) in *tenera* genotypes and one allele (550 bp) in *pisifera* genotypes. The identified shell specific CAPS markers benefits the oil palm breeders and seed producers in certification of high yielding seed

production by selective breeding of D×P crosses and it is useful to identify the true female sterile *pisifera* palms without going for recurrent selection of T×T or T×P crosses.

2.2 Oil Palm Breeding Programme in Malaysia

2.2.1 Development of Oil Palm Breeding Populations

Oil palm breeding and selection is synonymous to the development of Deli *dura* based on four palms introduced to Bogor in 1848. The early selections among open pollinated descendants of the Bogor palms, notably in the district of Deli in Sumatra, were not intended on commercial value but were meant for landscaping the avenues. Informal mass selection of the Deli plants for the provision of more avenues including those planted in Rantau Panjang, Kuala Selangor in 1911 were easy, as these palms were highly productive and bred true-to-type (Hartley, 1988). Supports by formal programmers at various centres in Malaysia and Indonesia since the 1920s gave rise to the Deli *dura* breeding population, widely used for seed production (Kushairi and Rajanaidu, 2000).

In 1920s, the Department of Agriculture (DOA) in Serdang and Elmina Estate initiated oil palm breeding programme in Malaysia using Deli *dura* materials. By 1933, two other companies, the Oil Palm of Malaya (OPM) of Kumpulan Guthrie Berhad in Ulu Remis and Elacis Estate and Societe Financiere de Caoutchouces (Socfin) in Johore Labis Estate started their breeding programmes (Kushairi and Rajanaidu, 2000). The programmes by DOA, Guthrie and Socfin resulted in the Serdang Avenue, Elmina, Ulu Remis and Johore Labis (Breeding Populations of Restricted Origin or BPRO)

(Rosenquist, 1986). Besides that, United Plantations Berhad introduced materials from Sumatera and Africa in 1927 and later their Research Department was formally formed in 1964 (Sharma and Tan, 1999). Other plantation companies such as Dunlops, Pamol, Golden Hope and Felda also started their breeding and seed programmes in 1950's and 1960's (Kushairi and Rajanaidu, 2000). Malaysian Agricultural Research and Development (MARDI) leased DOA oil palm breeding materials for 10 years. In 1979, Palm Oil Research Institute of Malaysia (PORIM) now known as Malaysian Palm Oil Board (MPOB) was formed to managed the oil palm genetic materials of the DOA collection.

The progress of oil palm breeding in Malaysia beside individual programme had benefited the industry from the joint researches between research centres in Malaysia and Africa since 1950's (Hardon et al., 1976). Within Malaysia, the notable collaborative programmes were the Cooperative Breeding Scheme (CBS), Oil Palm Genetic Laboratory (OPGL) and Sabah Breeding Programme (SBP) (Kushairi, 1998).

2.2.2 The *Dura/Tenera/Pisifera* Breeding Populations

The basic population in breeding programmes worldwide is almost exclusively derived from the Deli *dura* population from the four Bogor palms (Kushairi and Rajanaidu, 2000). The fruit characteristics of the materials are thick-shelled and spikelets of the bunch with short spike rather than long spines as found in African *dura*. The fruits are large and contain more oil bearing mesocarp than the African *dura*. The fruits also pale in colour and had slightly lower oil content than the African *dura* (Corley and Tinker, 2003).

Rosenquist (1986) traced the developments of breeding populations and formed the term Breeding Populations of Restricted Origins (BPRO). The Dura breeding populations developed in Malaysia were Serdang Avenue *Dura*, Elmina *Dura*, Highlands Estate *Dura*, Ulu Remis *Dura*, Banting *Dura* and Johor Labis *Dura*.

The Serdang Avenue *dura* (SA) were widely used in seed production and breeding programmes in Malaysia and Africa (Rajanaidu et al., 1990). Fruits of SA palms were higher oil yielding and had a higher kernel to fruit percentage than the commercial Deli *dura* (Hartley, 1988). The Ulu Remis *dura* is the most widely distributed oil palm genetic material worldwide (Rosenquist, 1986). The Banting Deli *dura* was known for high number of relatively small bunches (Rosenquist, 1985).

In Malaysia and Indonesia, improvement of *tenera/pisifera* was based largely on the African programmes (Kushairi et al., 1999a). The most significant import to Malaysia was the AVROS cross, planted as BM119 in 1957 (Rao et al., 1999). Other importations included bulked *pisifera* pollen imported by Oil Palm of Malaya from Congo in 1947, these were crossed onto Deli *duras* to produce *teneras* which were then intercrossed or crossed with Nigerian *teneras*. The resulting crosses were planted at four time normal density and the *duras* and *teneras* were removed once the fruiting started. The *pisiferas* formed the PA series of Guthrie Research Chemara (Yong et al., 1999).

At present, there is a capacity to produce nearly 400 million D×P seeds in Indonesia, Malaysia and other countries (Rajanaidu et al., 2016). The Djongo/SP540 from Congo, the Yangambi (Congo), Calabar (Nigerian), Ekona (Cameroon), La Me (Ivory

Coast), URT (Guthrie) and AVROS (Indonesia) are the major contributors of the paternal (*pisifera*) lines used in seed production and breeding (Kushairi et al., 2011). On the maternal side, the Deli *dura* derived from four Bogor palms played a major role. To date, the D×P known as *tenera* was used as planting material in Malaysia (Rajanaidu et al., 2016).

2.2.3 Breeding Objectives in Oil Palm Breeding

The discovery of shell thickness inheritance in oil palm by Beirmaert and Vanderweyen (1941) is a major contribution to the oil palm industry. Unlike the single gene inheritance for shell thickness, majority of the economically important traits in oil palm are under polygenic control. Quantitative estimations of genetic variance and heritabilities have been attempted by oil palm breeders to provide information to improve breeding efficiency (Hardon and Thomas, 1968). In oil palm breeding, the main objectives are to increase oil yield, short palms, to improve oil quality, resistant to diseases, physiological traits and exploitation of genotype × environment (G×E) interaction (Rajanaidu et al., 2000).

The oil yield per palm is the product of the fresh fruit to bunches (FFB) per palm and oil content per bunch. The FFB per palm per year is the product of the number of bunches and the average of bunch weight. In bunch analysis (Blaak et al., 1963), fruit to bunch (F/B), mesocarp to fruit (M/F) and oil to wet mesocarp (O/WM) are estimated. Similarly, the kernel to bunch (K/B) ratio is computed by multiplying the F/B and kernel to fruit (K/F) ratio. Several variables are involved in the computation of oil yield. It is less

heritable and highly influenced by the environment. Therefore, selection for the most heritable bunch quality components such as M/F and K/F may be more effective to improve yield (Rajanaidu et al., 2000).

The D×P planting materials grow at the rate of 40-75 cm per year and are difficult to harvest. The dumpy E206 from Elmina *dura* possesses genes for extremely low height increment and this trait has been introgressed into *pisiferas* to produce shorter D×P planting materials (Soh et al., 1981). Commercial planting material produced by crossing the dumpy AVROS *pisifera* with Deli *dura* is 20% shorter in terms of height. Germplasm collections in Nigeria by PORIM have provided an important source of dwarf palms for breeding. From the Nigerian germplasm, Population 12 was unique and it has many attributes such as high yield, short and compact (Rajanaidu et al., 2000).

Crops such as soya bean and maize had their yield increased by either increasing their planting density using specific genotypes or by breeding with high harvest indices (Breure and Corley, 1983). In the oil palm, there is a sufficient genetic variability for a higher planting density and also palms with higher bunch index. Efficiency in conversion of dry matter has to be increased and channeled into short palms with shorter fronds thus minimizing interpalm competition (Rajanaidu and Zakri, 1988).

Genotypes differ in their response to environmental changes, such as rainfalls, soil and type of agronomic practices. Rajanaidu et al. (1993) studied the G×E in the germplasm material and the D×P planting materials. The D×P showed yield ranging from 85 kg/p/yr at Kudat with poor soil to 184.4 kg/p/yr at Carey Island with fertile soil. The

pooled data over the sites showed significant $G \times E$ for yield, bunch number and average bunch weight. The stability of the progenies was studied by regression analysis and coefficient of variation (CV). The experiment involving germplasm materials showed that the FFB yield ranged from 148 kg/p/yr at Kluang with less fertile soil to 173 kg/p/yr at Klang with more fertile soil.

2.2.4 Breeding Methods in Oil Palm

A modified recurrent selection (MRS) is practiced by Malaysian oil palm breeders. It involves intercrossing among the selected parents and carrying progenies forward to the next cycle. Unlike the reciprocal recurrent selection (RRS) that is largely used by IRHO, MRS allows introduction of new genes into the breeding programme to increase the genetic variability (Hardon, 1970). In this method, a random set of *duras* are crossed in various combinations using North Carolina Mating Design (NCM 1) (Comstock and Robinson, 1952). NCM 1 is a nested design where every male is mated to a number of females in a set. It can be used to estimate genetic variance components such as additive and dominance variances as well as narrow-sense heritability (h^2_n). The specific and general combining ability of the *pisiferas* also can be estimated. If the mean performance of a *pisifera* is high with a number of Deli *duras*, then the *pisifera* is considered to have a good general combining ability (GCA). After four years of planting and yield recording, the palms are selected for seed production. Outstanding *dura* palms are selected for seed production so it can be recombined to generate the next cycle of improved *dura* mother palm (Rajanaidu and Jalani, 1995).

2.3 Collections of Oil Palm Germplasm

2.3.1 Genetic Base of Oil Palm

During 1975, the oil palm breeding materials were based on an extremely narrow genetic base. The narrowness of gene pools had been a major obstacle to selection progress in oil palm (Arasu and Rajanaidu, 1975). It was the concern generated by this situation that provided the initial development for the prospection of oil palm genetic materials in the centres of origin such as West Africa. Genetic resources programme involved four major steps that are germplasm collection, evaluation, utilization and conservation. A genebank is a place where collected genetic resources are preserved in the form of seeds, plants or tissues. In Malaysia, the first introduction of germplasm was carried out by Malaysian Agricultural Research and Development Institute (MARDI). It was involved in a joint oil palm germplasm prospection with the Nigerian Institute for Oil Palm Research (NIFOR) in 1973. Open pollinated bunches were taken from 919 palms (595 *duras* and 324 *teneras*) from 45 sites. A very detailed evaluation was done in Malaysia (Rajanaidu and Rao, 1988). This collection was transferred to PORIM which was established in 1979 (Rajanaidu, 1994).

The objectives of the oil palm genetic resources are to find new source of genes to broaden the genetic base of the current oil palm breeding programme and to conserve the oil palm germplasm of natural palm groves in Africa that are disappearing due to rapid development of the land. Another objective is to introduce novel genes such as fatty acid composition, high iodine value, dwarfness and high bunch index. The current breeding

materials had limited variation on these traits. Besides that, this programme can also create new oil palm breeding population based on the new introductions, understand the level of natural variation of the oil palm species and to study the organization of variation between and within natural oil palm groves. The information can be useful to devise a sampling strategy for germplasm collection in the wild and conservation (Rajanaidu, 1986).

2.3.2 Collections and Establishment

The objective of germplasm collection is to gather the maximum amount of genetic variability in the minimum number of samples (Marshall and Brown, 1975). The basic sampling strategy is to collect a few individuals per site from as many sites as possible over a broad range of environments. PORIM carried out a number of plant exploration in Africa and South America since 1981. The collections were carried out with the cooperation of the host countries. Lawrence and Rajanaidu (1986) used fruit and vegetative measurements data from 200 families, five from each of 40 sites from the PORIM Nigerian collection to determine the best sampling strategy for collecting and conserving a wild oil palm population. A sampling method for the collection of germplasm is devised based on rainfall pattern, soil types and density of palm groves. Five to ten palms per sites were sampled. The number of sites visited in a country depends largely on the density of the palm groves. A bunch was harvested from each of the sampled palms and the fruits from each bunch were kept separate until field planting. The seedlings derived from a bunch were considered as an open-pollinated family. The

collections have been made in Cameroon (1984), Zaire (1984), Tanzania (1986), Madagascar (1986), Angola (1991, 2010), Senegal (1993), Gambia (1993), Sierra Leone (1994), Guinea (1994) and Ghana (1996) (Rajanaidu, 1994).

2.3.3 Evaluation and Selection

The oil palm genetic materials collected were planted in the form of open-pollinated families at PORIM Research Station, Kluang, Johor. Experimental designs such as cubic lattice, randomized complete block (RCBD) and completely randomized design (CRD) were used to study the performance of the materials. The data were collected on an individual palm basis. They were fresh fruit bunches yield, oil yield and bunch quality components, vegetative measurements, fatty acid composition, physiological parameters and flower census.

Based on the performance of populations and families within populations, elite palms were selected for high yield, dwarfness, high iodine values and high kernel content. *Tenera* palms yielding more than 10 tonne oil/ha/year have been discovered in the Nigerian collection. They are also short, their annual height increment is 15 to 25 cm compared to the current D×P materials with 45 to 75 cm (Rajanaidu and Rao, 1988). Breeding for high kernel oil is also important in oil palm breeding. An economic analysis shows that breeding for the highest possible content of kernel in oil palm fruits yields the highest return from the oil palm (Rajanaidu and Jalani, 1994a). Some of the Nigerian families had a mean kernel to bunch (K/B) of more than 12% compared to 6% in the

current planting materials. These findings can be useful to double up the kernel content in future oil palms planting material (Rajanaidu et al., 1979).

2.3.4 Utilization of Elite Oil Palm

Oil palm breeding and selection is time consuming and difficult. Usually the newly introduced gene pool has no potential for direct exploitation so it has to be introgressed into existing advanced breeding material. The new gene pool will be considered for immediate exploitation if it possesses interesting traits and acceptable yields (Rajanaidu et al., 2000). The oil palm germplasm has been evaluated and some of the materials are being utilized in a number of ways for oil palm improvement.

The Nigerian collection *teneras* had oil yields comparable to current planting materials. The dwarf elite *tenera* palms yield more than 200 kg FFB per palm per year and oil to bunch of more than 28%. Attempts had been made to clone the elite palms by tissue culture techniques. The inflorescences of these elite palms are used as explant. Elite Nigerian *dura* were also progeny tested with the advanced *pisiferas* to study their combining ability. Similarly, the Nigerian *pisiferas* and *teneras* were also progeny tested to study their combining ability with Deli *duras* (Rajanaidu, 1994).

The outstanding *dura* and *pisifera* palms from the Nigerian collection were being used to initiate a new breeding programme, with the objectives of producing superior alternatives to the current Deli *duras* and *pisiferas*. Special crossing programme have

been developed to produce high yielding dwarf plant materials and high iodine value of oil palm seeds (Rajanaidu, 1994).

Using the current oil palm material and the elite Nigerian material, MPOB has developed PORIM Series 1 (PS1), PORIM Series 2 (PS2) and PORIM Series 3 (PS3). Planting material (PS1) was based on MPOB-Nigerian population 12. The original population 12 was planted in trial 0.149 in Kluang in 1975. The next generation of population 12 was evaluated in trial 0.337, Ulu Paka in 1994. Generally, the population 12 *teneras* were shorter than the D×P AVROS control. Nine *pisiferas* from outstanding progenies were tested with 33 Deli *duras* in trial 0.338 at Ulu Paka. The deli *duras* had large fruits and thick mesocarp compared to MPOB-Nigerian palms. The progeny tested crossed were evaluated at EPA, Johore in trial 0.869. Some of the crosses had total economic product (TEP) of 10.5 tonnes per hectare and were 30 percent shorter than the D×P control. Hence, it is easier to harvest and more amenable for mechanization (Rajanaidu et al., 2013).

The first Angola germplasm that was collected in 1991 and has been planted and evaluated in Kluang, Johor showed high potential for FFB, oil yields and other traits such as large fruit *dura*, high vitamin E and long stalk (Kushairi et al., 2003a). Kushairi et al. (2003b) reported that several palms with stalk bunch lengths 20 – 30 cm was identified within the Angola collection. Bunch with long stalk are useful for the ease of harvesting and could contribute to higher productivity. Based on the data from the first collection, MPOB decided to carry out the second Angola germplasm prospection in 2010 to

improve the Malaysian oil palm materials (Marhalil and Rajanaidu, 2011). Marhalil and Rajanaidu (2011) reported that the Angolan germplasm collected in 2010 had good potential traits for breeding with several characteristic such as compactness for frond length, long stalk and high mesocarp which can be further evaluated and utilized to generate high planting material.

Harvesting oil palm bunches is one of the major elements in the cost of production. In addressing the issue, MPOB has released a number of genotypes such as dwarf MPOB-Nigerian population 12, palms with long stalk bunches, virescens palms to discerns ripeness of fruits and low lipase to maintain oil quality even if there is a delay in harvesting and processing. To date, up to 13 PORIM series had been released to the industry (Rajanaidu et al., 2016).

2.3.5 Studies of Oil Palm Germplasm at Molecular Level

Studies on oil palm germplasm materials at molecular level had also been done by several researchers and breeders. Studies using molecular markers on the genetic diversity in the MPOB oil palm germplasm are important for the establishment of a core collection (germplasm with minimal repetitive genetic and maximal genetic diversity). The estimated genetic distance determined using molecular marker data may prove useful in developing appropriate sampling strategies for conservation and also for future collection expeditions (Zulkifly et al., 2012). In his study, a total of 330 palms originating from 11 countries were screened using 10 expressed sequence tag-simple sequence repeats (EST-SSR). The 10 EST-SSR primers used successfully differentiated and clustered the

germplasm population indicating high genetic diversity in the germplasm collections thus revealing that the germplasm collection is a good source for new genes related to novel traits which can be introgressed into current planting materials.

Ong et al. (2015) studied 219 oil palms collected from two natural Angolan populations using a total of 62 single nucleotide polymorphism (SNP) that were designed from oil palm genomic sequences and converted to cleaved amplifies polymorphic sequence (CAPS). The results obtained in the study signify the successful application of nine informative SNPs to analyze the diversity of the two natural oil palm populations collected from Angola.

Okoye et al. (2016) used nine SSR markers to study the genetic relationship among 26 elite oil palm materials from Nigeria and Malaysia. The 11 Malaysian genotypes included two *dura* and two *pisifera* of advanced breeding lines, three palms from natural populations of Nigeria and two palms each from Angola and Madagascar natural oil palm collections. The various oil palm provenances showed significant genetic differentiation indicating the existence of a genetic structure among the materials used. The high genetic diversity observed among the MPOB's germplasm materials highlights the need for proper characterization of entire NIFOR oil palm germplasm with SSR markers to facilitate effective utilization in the breeding programme.

Li-Hammed et al. (2015) also studied the genetic diversity of oil palm germplasm using two hierarchical clustering methods; single linkage clustering method and Ward's method. 595 oil palm genotypes grouped into 44 accessions were morphologically

Characterized for yield traits, bunch quality traits, morphological and physiological traits and fatty acids traits. The two clustering methods classified the accessions into eight groups and the oil palm germplasm with different characteristics were identified and the genetic distance within and between the groups was estimated.

Palm oil comprises mainly triacylglycerols (TAG) that account for about 0.95 of its composition. Lypolysis of TAG releases free fatty acids that are then oxidized, impairing oil quality therefore lower endogenous lipase activity is desirable for better quality oil. Wong et al. (2016) studied a total of 148 oil palm germplasm from Angola, Cameroon, Guinea, Nigeria, Senegal, Sierra Leone, Tanzania and Zaire, screened for lipase activity using the novel non-radioactive method. The analysis revealed significant differences in lipase activity in palms from different countries, populations and families and palms with low and high lipase activities were identified. The three palms with the lowest free fatty acids (FFA) values were from Nigeria, Senegal and Guinea.