HISTORICAL REVIEW OF OIL PALM BREEDING FOR THE PAST 50 YEARS – MALAYSIAN JOURNEY

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ABSTRACT

The development of oil palm breeding in Malaysia from 1960- 2010 is covered in this paper. Discovery of the inheritance of shell and DXP, crop diversification policy of the Government, formation of Federal Land Development Authority (FELDA), and availability of funds from World Bank to finance oil palm industry provided much the impetus for accelerated growth. Prior to 1960, the Department of Agriculture of Malaysia and the private sector (Guthrie, Harrisons and Crosfield (H&C), Socfin, United Plantations (UP)) have introduced the basic oil palm breeding material from Indonesia and Africa. The Deli *duras* from Marihat Baris, Elmina including dumpy E206, importation AVROS pollen by H&C and Department of Agriculture (DOA), DOA *pisifera* 27B & 29/36, Guthire URT (Deli and Congo) formed the foundational breeding materials available in the country. A number of breeding materials exchange programmes were initiated in Malaysia i.e. Cooperative Breeding Scheme (CBS) in 1956, Oil Palm Genetic Laboratory (OPGL) in 1963 and Sabah Breeding programme (SBP) in 1964. In early stages DOA, Guthrie, H&C, Socfin, Felda, Pamol (Unilever) and Dunlops were actively involved in oil palm breeding and seed production. In 1979, Palm Oil Research Institute of Malaysia (PORIM) was formed. A large oil palm (*guineensis* and *oleifera*) germplasm was collected in Africa and Central/South America. The first collection was made in 1973 under Malaysian Agricultural Research and Development Industry (MARDI) and the last collection was in 2010 in Angola. In 1983, Socfin breeding programme and seed production was closed down. Meanwhile the Pamol (Sabah & Kluang) and Dunlops oil palm breeding programme were merged into IOI. The Sime Darby, Guthrie, H&C (Golden Hope) breeding programmes were consolidated into a single entity under Sime Darby. Meanwhile a number of new seed producers such as Applied Agriculture Resources Sdn. Bhd. (AAR), Borneo Samudera, Sarawak Plantation Agriculture Development Sdn. Bhd. (SPAD), NALFIN Planting Material Sdn.Bhd. (NALFIN), RISDA Semaian Landskap Sdn. Bhd. (RISDA), Federal Land Consolidation and Rehabilitation (FELCRA), Genting Plantations Berhad (GENTING), DOA Sabah, Malaysian Palm Oil Board (MPOB), IJM Plantations Berhad (IJM), Sasaran Ehsan Utama Sdn. Bhd. (SEU), PPNJ and KULIM Sdn. Bhd. (KULIM) have started seed production programme largely by obtaining advanced breeding materials from MPOB and also the leasing mother palms and sourcing pollen from MPOB. Most of seed producers use ex-Chemara Deli *duras* as female parents. AVROS, dumpy AVROS, Yangambi, dumpy Yangambi, dumpy Yangambi X AVROS, Calabar, Ekona sources are used as *pisiferas* for seed production and breeding. Recently hybrid *duras* (Deli *duras* X Nigerian *duras*) and Nigerian population 12 *pisiferas* are being tested as new parental materials. With the introduction of pollinating weevils from Cameroons to Malaysia in 1981, there was a spike in the *dura* contamination in the oil palm DXP planting materials. Several quality control measures were taken by oil palm

breeders to minimize the contamination. Currently the *dura* contamination is less than 1% in DXP planting material.

Oil palm tissue culture programme was started in early eighties in Malaysia. Current production is about 5 million ramets compared to 120 million of DXP seeds. Meanwhile, tissue culture floral abnormalities had cast a certain level of risk in planting oil palm clones. MPOB and members of the industry have invested heavily to discover the DNA markers which can be used to identify and discard abnormal plantlets in the nursery and before field planting.

There is a potential application of tissue culture technique to multiply parental palms (which have been progeny-tested) to produce semi- and bi- clonal seeds. A number of companies such as AAR, UP and FELDA Agricultural Services Sdn. Bhd. (FASSB) have since been marketing semi-clonal seeds.

Internationally, there is a big demand for Malaysian oil palm planting materials. This is due to various quality control measures Malaysia has implemented and they include SIRIM standards for mother palms, progeny tested material and inspection of facilities by SIRIM officers. Seed producers need MPOB licence to operate. MPOB samples DXP seeds produced by various companies (once in 5 years) and evaluate the materials for performance compliance and contamination checks independently.

Malaysian oil palm breeders have contributed much to the science of oil palm breeding by publishing papers in areas of breeding methods, best linear unbiased prediction (BLUP), experimental designs, genotype X environment (GXE) interaction, molecular breeding and disease tolerance.

With the discovery of shell gene at the molecular level and following publishing the oil palm genome sequence data, we expect further integration of conventional and molecular breeding techniques.

In the past, the field of oil palm breeding had attracted students with PhD to carry out research. Now, the top students select the field of biotechnology and very few opt to study quantitative genetics. We hope this trend will reverse in the future.

Introduction

In 1960, the oil palm yield was 3.2 tonnes per hectare (Yusof, 2000). Oil palm DXP seed production capacity has more than doubled from 50 million in 1995 to 109 million in 2000 and currently at 124 million in 2010 (Table 1).

Table 1. Oil Palm DXP Seed Production in Malaysia

Year	**Seed Production**		
	Peninsular Malaysia	**Sabah & Sarawak**	**Total**
1994	78,057,422	4,050,077	82,107,499
1995	70,973,288	5,997,020	76,970,308
1996	73,944,220	4,842,216	78,786,436
1997	92,391,196	4,837,476	97,228,672
1998	96,081,675	4,497,415	100,579,090
1999	97,757,746	4,186,626	101,944,372
2000	105,395,339	3,919,123	109,314,462
2001	96,982,262	4,765,780	101,748,042
2002	87,983,655	4,497,483	92,481,138
2003	87,286,360	4,187,998	91,474,358
2004	101,407,943	5,273,009	106,680,952
2005	110,436,961	7,166,994	117,603,955
2006	97,785,391	14,242,175	112,027,566
2007	101,543,570	16,371,767	117,915,337
2008	110,099,733	21,551,618	131,651,351
2009	109,100,196	23,442,564	132,542,760
2010	99,427,195	24,587,458	124,014,653
2011	99,905,428	28,148,284	128,053,712
2012	96,656,882	34,036,586	130,693,468

Source: MPOB (2013)

The discovery of shell gene (*dura*, *tenera*, *pisifera*) in the oil palm fruits by Beirnaert and Vanderweyen (1941) in Congo forms the foundation of all commercial production of *dura* X *pisifera* (DXP) planting material in Malaysia. The knowledge of the single gene inheritance has then been fully utilized, resulting in a tremendous boost for oil yields. The oil palm was introduced to South East Asia in the form of four seedling planted in the Botanic Garden at Bogor (Indonesia) in 1848. There is little information regarding the origin of these palms. There are grounds to suggest that all four seedlings originated from one parent (Hartley, 1988). Using seeds from these four Bogor palms, several small plots of palms were established in different parts of Indonesia including the district of Deli in Sumatra. Materials from these plots were used to establish ornamental avenues on tobacco estates in Sumatra. These Deli *dura* populations formed the backbone of all the oil palm breeding materials in Malaysia. The 86 Serdang Avenue palms originated from Bogor palms were planted in Elaeis Estate in 1931 and later introgressed with Ulu Remis selections to produce Chemara Deli *duras.*

Apart from the individual programmes in oil palm breeding, collaborations between breeding stations had benefited the industry. Such an example was by Socfin of Malaysia which participated in the 'international experiments' with institutes in West Africa especially IRHO. Within Malaysia, the notable collaborative programmes are the Cooperative Breeding Scheme (CBS), Oil Palm Genetic Laboratory (OPGL) and Sabah Breeding Programme (SBP) as shown in Figure 1.

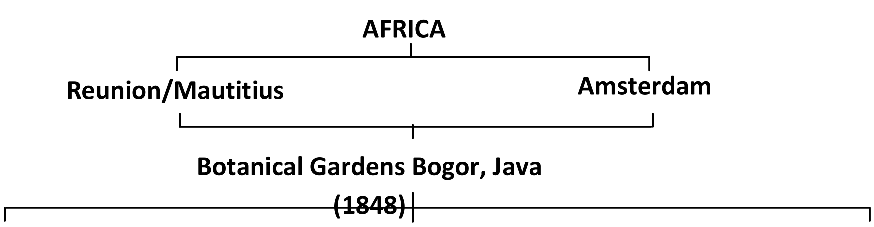
The CBS was initiated in 1956 (Heath, 1958) when the United Planting Association (UPA) and DOA pooled all the oil palm breeding programmes of Ulu Remis (Guthrie), Klanang Baru (Golden Hope), Johor Labis (Socfin) and Jenderata Estates (UP). The objective of the scheme was to develop the Dumpy and of the *tenera* palms. Nurseries of the four 'Host Estates' were supplied with seedlings from the Federal Experimental Station (FES), DOA in Serdang (Heath, 1958).

OPGL was formed in 1963 of consortium by four plantation companies comprising Kumpulan Guthrie Sdn. Bhd. (KGSB), Harrisons Malaysian Plantations Sdn. Bhd. (HMPB), Dunlop Estates Bhd. and Pamol Plantations Sdn. Bhd (PAMOL). This consortium was responsible for the country's first large-scale oil palm germplasm acquisition, evaluation, utilization and enrichment of the many diverse oil palm genetic material of *E. guineensis* and *E. oleifera* used for planting in their estates (Table 2). In 1964, Dr. J.J. Hardon was employed to head the consortium based at Guthrie Research Chemara, Layang-layang, Johor. Dr. R.H.V. Corley was subsequently employed to guide the team in choosing future oil palm selections using physiological parameters (Chan et al., 1986).

Table 2. Introduction of genetic material by OPGL

	Year Planted	Experiment No.	
		HMPB	Guthrie
<u>E. guineensis</u>			
***Dura* Programme**			
Historical collection of old *dura* material in Bogor, Sumatra and Malaysia	1970	PT49	
***Tenera* and *Pisifera* Programme**			
Elite commercial DXP from Nifor	1967	PT29	GB31
Introduction TXT from Nifor	1967	PT30	
Crosses obtained from Nifor, Camerouns and IRHO	1968	PT33	
Open pollinated *teneras* from Bamenda (Camerouns)	1969	PT40	GB57
Crosses Ex-Yangambi material with BM119 and Socfin *teneras*	1969	PT42	
Ghana Ex-Nifor for DXT	1972	PT53	
Binga (Zaire) TXT	1973	PT54	GB67
Disease Resistance			
Wilt resistance material from the Camerouns	1968		GB46
<u>E. oleifera</u>			
Collection from Panama, Costa Rica and Columbia			
E. oleifera, F1 (GXO), F2 (GXO) and backcross (GXF1)	1969	PT50	GB62
E. oleifera (open-pollinated)	1971		GB64a GB64b

SBP was an effort by the State Government in 1960s to produce locally tested oil palm seeds to support the development of the industry in Sabah. The Ulu Dusun research station at Sandakan was set up in 1962 for this purpose. The breeding materials were obtained through an exchange scheme organised by C.W.S. Hartley who was engaged by the State Government. It involved four Malaysian and three African participants. The programme contained African *tenera* selections as male parents crossed with Malaysian Deli *dura* selections. The Malaysian participants were Chemara (Guthrie), HMPB (Golden Hope), Socfin and DOA. The three African companies that were involved in this project was Nigerian Institute for Oil Palm Research (NIFOR), Unilever Nigeria and Unilever Cameroon (Rajanaidu et al., 1986).



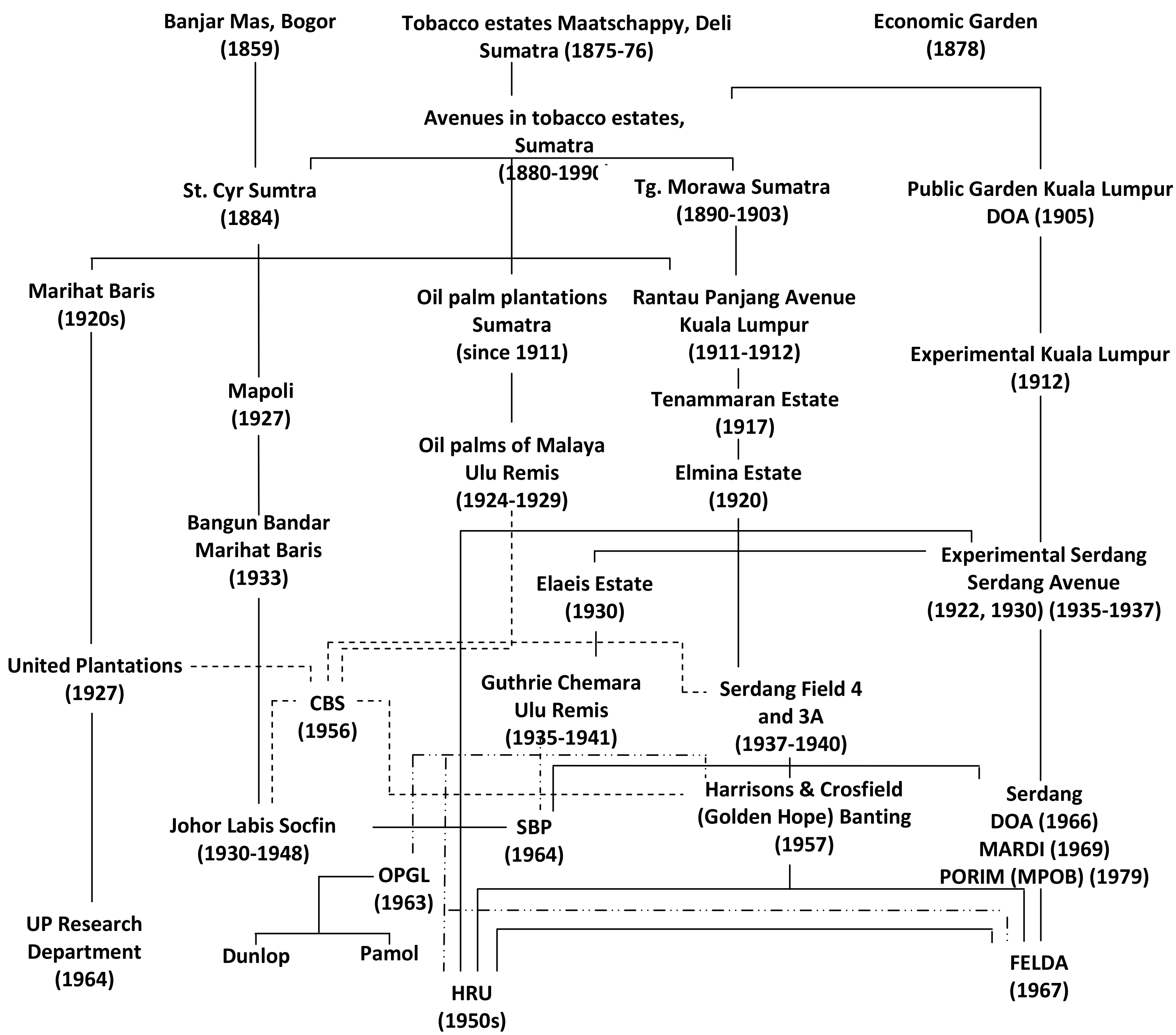


Figure 1. History and developments of the Deli *dura* in Malaysia (Kushairi, 1992).

Oil palm commercial cultivation began in 1917 in Malaysia, but initial growth of the industry was slow. It was only during the last 50 years that plantation development was accelerated through large-scale investments in the cultivation of oil palm. It is one of the approved crops for diversifying the country's agricultural development. Malaysia's preference for oil palm has led to a rapid expansion of its planted areas at the expense of rubber and other crops over the last four decades (Yusof, 2007). Current area and production of palm in the country has increased. The planting material is derived from narrow genetic base. To broaden the genetic base, MPOB collected *Elaeis guineensis* and *Elaeis oleifera* germplasm from centers of origin of African and South American oil palm as listed in Table 2 (Rajanaidu, 1994; Kushairi *et al.*, 2011).

MPOB has assembled the largest *E. guineensis* germplasm collection in the world. The first collection was made in 1973 with the collaboration with MARDI and NIFOR. Later collections were made in Nigeria, Cameroon, Zaire, Tanzania, Madagascar, Senegal, Gambia, Sierra Leone, Guinea, Ghana and Angola (Table 3).

MPOB has collected several *E. oleifera* populations since 1982 from Colombia, Panama, Costa Rica, Honduras, Nicaragua, Suriname, Peru and Ecuador as shown in Table 3 (Rajanaidu and Ainul, 2013). A programme to collect *E. oleifera* for evaluation and utilization in the natural groves of Costa Rica, Panama and Colombia was initiated by United Brands Company in Central America in 1967. Breeders from Socfin, OPGL and UP made collections in Colombia, Panama and Costa Rica and subsequent introduced to Malaysia in 1967, 1969 and 1980 respectively. The low yield of the *E. oleifera* is a major obstacle for the species to be utilized as commercial planting materials. However, it stands out against *E. guineensis* for traits such as oil quality, height and high carotene. Expeditions by Rajanaidu and Kushairi to Peru, Ecuador, Colombia and Brazil in 2004 were made especially for collections on materials with interesting fruit characters such as good fruit set , low pathernocarpy (less than 10%), high mesocarp to fruit and reasonable stalk length.

In oil palm breeding, there have been six objectives stated by Rajanaidu et al. (2000). The objectives are to increase oil yield, looking for short palms, improve the oil quality, finding for disease resistance palm, focusing on some important physiological traits (oil to bunch, total dry matter and bunch index) and exploiting the GXE interaction. In 2005, MPOB has drawn up a list of 10 priority traits (Mohd Din et al., 2005). The traits are high oil yield, *Ganoderma* tolerance, high bunch index, low height increment, long stalk, low lipase, high oleic acid, large kernel, high vitamin E and high carotene. Some of these traits have been successfully bred and listed in MPOB's Transfer of Technology (TOT) as the PS series.

Table 3. List of *E. guineensis* and *Elaeis oleifera* germplasm collection available in MPOB

Species	Country of Origin	Year of Collection
Elaeis guineensis	Nigeria	1973
	Cameroon	1984
	Zaire	1984
	Tanzania	1986

	Madagascar	1986
	Senegal	1993
	Gambia	1993
	Sierra Leone	1994
	Guinea	1994
	Ghana	1996
	Angola	1991, 2010
Elaeis oleifera	Nicaragua	1982
	Honduras	1982
	Costa Rica	1982
	Colombia	1982, 2004
	Suriname	1982
	Brazil	1982, 2004
	Panama	1982
	Peru	2004
	Ecuador	2004

Currently, there are 13 PS series with PS1 being designated as slow height increment of the Nigerian population 12. PS2 is the high iodine value of the Nigerian palms from trial 0.151. PS3 is the high kernel palms in response to the lauric oils demand. PS4 is the high carotene in the *E. oleifera*. Thin-shell *teneras* are the attributes of the PS5. PS6 is the large fruit *duras* while PS7 focuses on the high bunch index. PS8 features high vitamin E of the *E. guineensis* while the peach palm (*Bactris gasipaes*) for palm heart production makes PS9. For ease of harvesting, the long stalk palms from the Angola population give rise to PS10. PS11 also contributes to high carotene from *E. guineensis* instead of *E. oleifera*. Lastly we have PS12 and PS13 which are known for then high oleic and low lipase respectively.

Discovery of hybrids (*Elaeis guineensis* X *Elaeis oleifera*) resistant to fatal yellowing in Colombia led to the establishment of the first commercial plantation (Turner, 1981). The hybrid was also found to be tolerant to the bud-rot disease in Latin America and vascular wilt in Africa (Amblard et al., 1999). It is also been advocated as promising source of new genetic variation in oil palm (Meunier and Hardon, 1976). The interspecific hybrids of the *E. oleifera* however have low oil yield as compared to the DXP commercial materials.

MPOB, UP and FELDA carried out extensive research on inter-specific hybrids. UP has planted nearly 500ha to produce hybrid oil for commercial purposes. For the *E. oleifera*, the introgressed progenies of Panama X Colombia group have the highest fresh fruit bunch (FFB) yield with 139.98 kg/palm/year mainly due to their high bunch number (BNO) of 12.67 bunches/palm/year and average bunch weight (ABW) of 10.23kg/palm/year. The Panama X Colombia group also showed the best mean fruit weight (MFW), oil to dry mesocarp (O/DM) fruit to bunch (F/B) and oil to bunch (O/B) ratio (Noh et. al., 2012).

The low oil yield of the *E. oleifera* and its interspecific hybrid compared to the DXP commercial planting material has led to the planting of backcrosses to overcome the problem. First generation backcrosses (BC I) were created using interspecific (OXP) hybrids as the maternal parent and *E. guineensis* var. *pisifera* as the paternal parent. Backcrosses however did not show much impact on the average bunch weight. An active backcross programme is being pursued by MPOB, UP and FELDA. In MPOB, the best FFB yield performer in the backcross programme was progeny PK1298 with 94kg/palm/year and its O/B was 16.27 % (Noh et. al., 2012).

Tissue Culture

In Malaysia, the current production of ramet has reached five million but still a struggle for the 11 laboratories nationwide in reaching the 40 million plantlets target by 2017 (Kushairi et al., 2011). The time for an oil palm tissue culture plantlet to be fully grown to pre-nursery stage from explant requires 2 to 3 years. In addition, the tissue culture process has incurred much loss due to the low conversion rate of explants to callus (approximately 19%) and from callus to embryoid stage (approximately 4%) (Corley and Tinker, 2003).

To successfully utilize the the tissue culture clonal propagation technique and the subsequent expanded efforts in clonal propagation, a number of critical issues need to be resolved or circumvented. The issues include somaclonal variation, cloning efficiency, ortet selection efficiency, recloning and the suspension culture system (Soh et al., 2010).

Breeding Methods

The major oil palm breeding programmes adopt either the modified recurrent selection or the modified reciprocal recurrent method. The former is practised by programmes particularly in the Far East while the latter is adopted by countries in West Africa and Indonesia advised by CIRAD (Soh et al., 2010).

- **Modified Recurrent Selection (MRS)**

The MRS is practised by a majority of oil palm breeders in Malaysia because the individual *pisiferas* are crossed to a number of Deli *duras* (Figure 2). NCM 1 breeding design can estimate the specific and general combining ability of the *pisiferas*. By looking at the mean performance of a *pisiferas* with a number of Deli *duras*, the GCA can be established. If the mean is high, the GCA (general combining ability) of the *pisifera* is considered good and vice versa. In specific combining ability (SCA) however, only certain crosses are high yielding. After a minimum of four years of yield recording, the palms are selected for seed production (Rajanaidu et al., 2000).

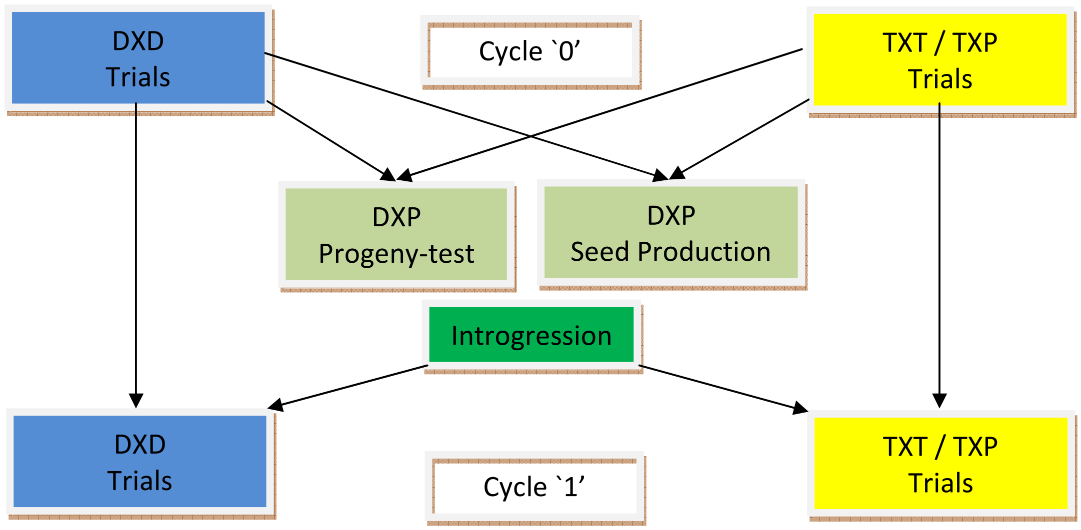
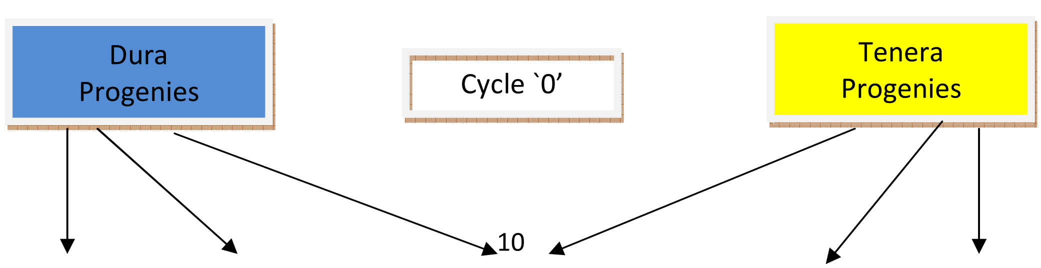


Figure 2. Modified recurrent selection scheme in oil palm

- **Reciprocal Recurrent Selection (RRS)**

The RRS differs from the MRS because in the RRS the parental test crosses and selfs of the parents are planted in the field at the same time. Within a period of up to 12 years, it is possible to produce a limited amount of good quality DXP seeds. The first oil palm programme which approximated to RRS was planned at Yangambi by Institut National pour l'Etude Agronomique du Congo Belge (INEAC) (Corley and Tinker, 2003). Comparing RRS with MRS, MRS takes a longer time because it involves two stages (Figure 3). The first is to evaluate the parental Deli *duras* and *pisiferas* in the form of TXT or TXP crosses. The second is to progeny test of the Deli *duras* with the elite *pisiferas*. It is possible to produce a large quantity of DXP seeds but it takes about 20 years to do so. In addition, the RRS requires a large experimental area to progeny- test the DXT crosses and selfs (Rajanaidu et al., 2000).



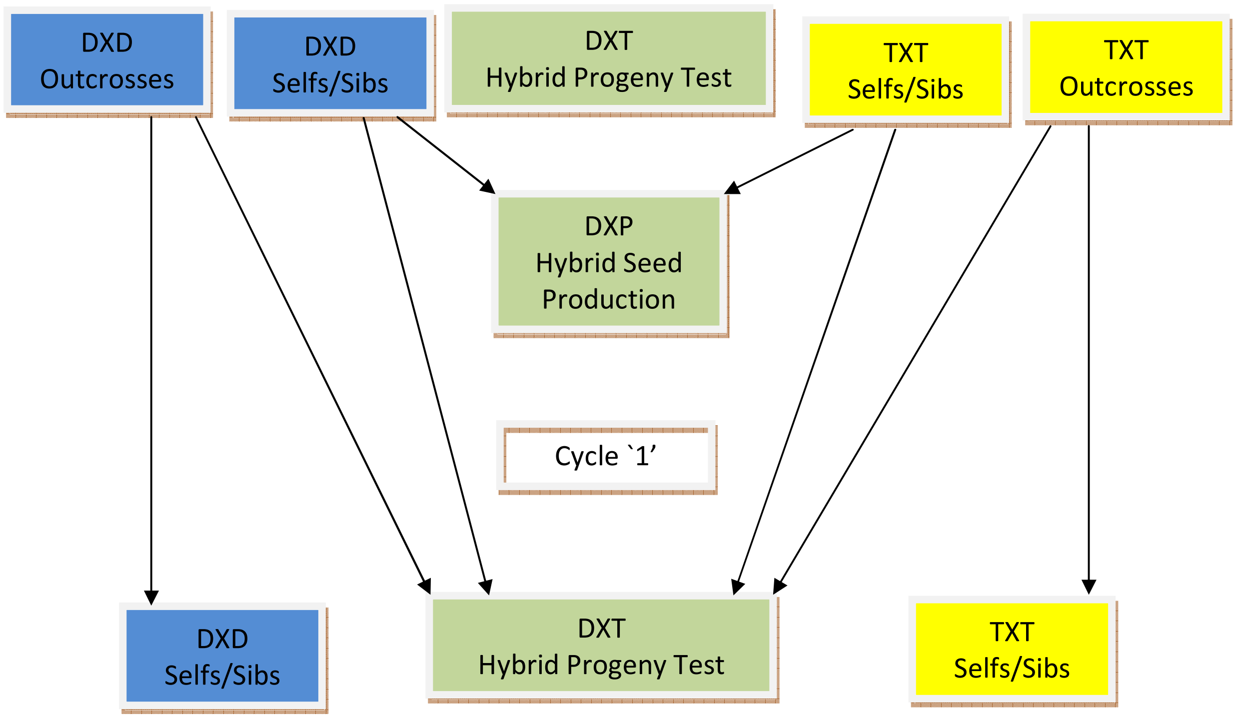


Figure 3. Reciprocal recurrent selection scheme in oil palm

- **Best Linear Unbiased Prediction (BLUP)**

The common methods of MRS or RRS are difficult to be applied successfully on hybrids Breeders wanting to select clones or seed parents from hybrid populations need to be able to predict the performance of the progeny or clones. The reliability of the identification of superior genotypes is important to the success of selection and therefore the genetic gains that can be achieved through breeding. However, in hybrids there are many factors that may impact negatively on the ability to predict performance. The sufficiently high correlation between predicted and observed hybrid performances, for most of the important traits, was obtained with highly unbalanced data sets. The BLUP coefficient should be sufficient for selection on the basis of the oil yield character, which is the main objective in most oil palm breeding programmes (Purba et al, 2001).

The BLUP technique incorporates best linear unbiased estimates of the fixed effects through generalised least squares with best linear unbiased prediction of the random genetic (breeding value) effects. The BLUP procedure has also the advantanges of the ability to incorporate information from relatives to improve the prediction of genetic trends such as different genetic groups and selection bias, treating them as fixed effects. In effect, what the BLUP procedure does is to treat the effects of secondary interest as ‘nuisance’ effects to be removed as fixed effects, consequently to give unbiased prediction of the genetic or breeding values of the parents (Soh, 1994).

Experimental Designs

To select individual palms for breeding, it is necessary to measure their bunch yield and to analyse the bunches for their oil and kernel content, vegetative measurements are also sometimes used. To breed from selected palms controlled pollination must be undertaken and the progenies produced must be planted in statistically valid experimental designs (Corley and Tinker, 2003).

- **Randomized Complete Block Design (RCBD)**

The germplasm and breeding materials collected from Africa and South America were planted in MPOB Research Station in Kluang, Johor. Experimental Design such as RCBD was used to study the performance of the materials. The various stages and time frame involved in the collection, establishment, evaluation and release of elite planting materials takes about twenty years.

- **Completely Randomized Design (CRD)**

CRD is a flexible design which can accommodate unequal size of progenies. It is especially useful to test disease tolerant progenies in the field. At MPOB DXP progenies are tested using both RCBD and CRD.

- **Genotype X Environment (GXE) Interaction**

Studies show that genotypes differ in their response to environmental changes such as rainfall, soil and agronomic practices. The level of GXE interaction in DXP planting materials is rather limited. However oil palm clones exhibit significant level of GXE. GXE interaction is important in breeding for disease tolerance at different locations. For example, for testing of *Ganoderma* is prominent in South-east Asia, and for *Fusarium* in Africa and Bud rot/Spear rot in South America.

- **Breeding for Disease Resistance**

In Malaysia, the oil palm faces chronic outbreaks of *Ganoderma* basal stem rot (BSR) which can result in significant economic losses. Plant resistance offers the cheapest form of control. Four species of *Ganoderma* have been associated with the oil palm. Three species have been reported to be pathogenic to oil palm with *Ganoderma boninense* being the most destructive (Idris et al., 2000; Nurniwalis, 2009). Based on the study by MPOB (Norziha et al., 2012), inter-crossed progenies of Elmina origin were more tolerant to *Ganoderma* compared to selfed progenies. Among progenies from Elmina origin, progeny MS3358 showed the most tolerance to BSR disease and is a potential progeny to be developed as *Ganoderma* tolerance materials.

Molecular Technologies

In oil palm research, molecular methods have been used in germplasm screening and breeding. Isozyme was first used in oil palm to study the genetic diversity in *Elaeis* spp. (Ghesquiere, 1985; Moretszohn, 1995). Restriction fragment length polymorphism (RFLP) has also been studied on oil palm (Mayes et al., 1997; Maizura et al., 2006). Amplified fragment length polymorphism (AFLP) and RFLP markers were utilized by Barcelos et al. (2002) to assess genetic relatedness between different accessions of the American oil palm. Simple sequence repeats (SSR) markers are now a popular choice to study the genetic diversity of the oil palm (Billotte et al., 2001; Zulkifli *et al.*, 2009; Ngoot Chin *et al.* 2010; Seng *et al.*, 2011 and Noorhariza *et al.*, 2012)

Quality Control of Planting Materials

To ensure production authenticity for desired productivity and sustainability of the oil palm industry, a Malaysian Standard (MS) was developed for DXP hybrid seeds and clones.

- **SIRIM Standards**

SIRIM Standard (MS157) states the minimum requirement for the seed production is as below:

1. Minimum Dura Yield of 160kg
2. Oil to Bunch of 16%
3. Oil Yield /Palm of 25.6kg

} Deli *dura* motherpalm

4. Minimum Progeny Yield of 160kg
5. Oil to Bunch of 24%
6. Progeny Oil Yield/Palm of 38.4kg
7. Minimum Kernel Yield of 3%
8. Oil Yield /Ha (136 palms) of 5.22 tons

} DXP progeny

The MS also includes requirements for ortet selection, guidance on production practices, packaging and legal matters. The ortets in generating clones must be from either three sources as below:

(a) materials of known pedigree and known performance of family and individual palms;
(b) materials of unknown pedigree and known performance from known seed producers; or
(c) materials from field-tested clones for recloning.

The minimum standard requires for selection of an ortets are 50kg/palm/yr oil yield and 27% O/B ratio, recorded over four consecutive years and five analyses respectively.

- **Licence for Seed Production**

MPOB's website elaborates the licensing of the production of oil palm seeds. Some of the regulation in Part 1 of the licensing states the prohibition against producing or selling without license as listed below:

1. Produce oil palm planting material;
2. Sell or move oil palm planting material, oil palm fruit, palm oil, palm kernel, palm fatty acids or palm oleochemicals;
3. Purchase oil palm fruit, palm oil, palm kernel or palm fatty acids;
4. Store oil palm planting material, palm oil, palm kernel, palm kernel cake, palm fatty acids or palm oleochemicals;
5. Commence construction of oil palm mill;
6. Mill oil palm fruit;
7. Commence construction of bulking facilities for oil palm products;
8. Survey or test oil palm planting material, oil palm fruit, palm oil, palm kernel, palm kernel cake, palm fatty acids or palm oleochemical; or
9. Export or import oil palm planting material, oil palm fruit, palm oil, palm kernel, palm kernel cake, palm fatty acids or palm oleochemical.

MPOB samples the DXP seeds produced by various companies (once in 5 years) and evaluate the material independently for performance and contamination.

Human Resources

In the past a number of oil palm breeders contributed to the science of oil palm breeding in Malaysia. Some of them are Jagoe, Hardon, Thomas, Ooi, S.C, Rosenquist, Hartley, Corley, Chan Kook Weng, Yong Y.Y, Tan Yap Pau, Lee Chong Hee, Soh Aik Chin, Rajanaidu, Mohaimi, Mustapha, Musa bin Bilal, Rao,V, Rafii, Kushairi, Ramachandran, M.K.Menon, Vanialingam, Arasu,N.T, Tam Tai Kin, Gray,B.S, Tan Teng Lai, Chin Chuek Weng, Mukesh Sharma etc. The list is not exhaustive. In the 70s, there was extensive training of oil palm breeders up to PhD level. Scholarships were provided to students for training both in local and overseas universities. The officers who have been trained in the 70s had retired and at present there is a large vacuum to fill the posts left by the retired plant breeders and agronomists. The government research institutes and the private sector have to accelerate the training programme in the field of applied biology.
In summary, the Table 4 gives the list of oil palm seed producers in Malaysia and the genetic background of the parental material used for the seed production.

Conclusion

In the period of 50 years (1960-2010), there was great transformation and development oil palm industry including oil palm breeding in Malaysia. We have seen the consolidation of the major oil palm plantation companies and their breeding programmes, the closing down of oil palm breeding programme and the mushrooming of numerous small oil palm seed producers. The export ban on Malaysian oil palm seeds has been relaxed partly. Quality control of planting material by SIRIM and MPOB minimized the supply of illegimate seeds in the country. With the availability of oil palm genome data and the discovery of shell gene at molecular level, the conventional breeding programme will be accelerated.

Table 4: Current Utilization of Germplasm by Seed Producers from Above Programmes

No.	Name	Location	Germplasm Utilization
1.	Felda Agricultural Services Sdn. Bhd.	Jerantut, Pahang	• Chemara Deli *duras* • IRHO *pisiferas* & Deli *duras* • IRHO Yangambi ML 161
2.	Stesen FASSB Bukit Besar	Kulai, Johor	Same as above
3.	Ebor Research (Sime Plantations Sdn. Bhd.)	Kluang, Johor	• Kulai Deli *duras* • MPOB AVROS
4.	Applied Agricultural Resources Sdn. Bhd.	Kluang, Johor	• Dumpy AVROS (DA) • Dumpy Yangambi (DY) • DA X DY • Chemara Deli *duras* • Semi - Clonal Seeds & TC

5.	Borneo Samudera Sdn. Bhd.	Tawau, Sabah	• SBP & MPOB *duras* • AVROS *pisiferas*
6.	Ulu Dusun Seeds Sdn. Bhd.	Tawau, Sabah	Same as above
7.	Kulim Sdn. Bhd.	Kota Tinggi, Johor	• MPOB Deli *duras* • MPOB AVROS • Dami Deli *duras* • Dami AVROS
8.	Golden Hope Agrotech Consultancy Sdn. Bhd.	Tawau, Sabah	• Banting Deli *duras* • Banting AVROS
9.	Golden Hope Agrotech Consultancy Sdn. Bhd.	Banting, Selangor	Same as above
10.	Guthrie Plantation & Agricultural Serves Sdn.Bhd.	Kluang, Johor	• Chemara Deli *duras* • Ex-URT *pisiferas*
11.	Highland Research Unit Sdn. Bhd.	Klang, Selangor	• Chemara Deli *duras* • AVROS Dumpy *pisiferas*
12.	IJM Plantations Berhad	Labuk, Sabah	• MPOB Deli *duras* • MPOB AVROS
13.	IOI Corporation Berhad	Tampin, Negeri Sembilan	• Chemara Deli *duras* • MPOB AVROS
14.	Pamol Plantations Sdn. Bhd.	Kluang, Johor	• Chemara Deli *duras* • SBP *pisiferas*
15.	Pamol Plantations Sdn. Bhd.	Sandakan, Sabah	Same as above
16.	RISDA Semaian dan Landskap Sdn. Bhd.	Dungun, Terengganu	• MPOB Deli *duras* • MPOB AVROS
No.	**Name**	**Location**	**Germplasm Utilization**
17.	Stesen Penyelidikan Pertanian Ulu Dusun	Sandakan, Sabah	• SBP *duras* • SBP *pisiferas*
18.	Sasaran Ehsan Utama Sdn. Bhd.	Sandakan, Sabah	• MPOB Deli *duras* • MPOB AVROS
19.	Stesen Penyelidikan MPOB Kluang	Kluang, Johor	• MPOB Deli *duras* • MPOB AVROS
20.	United Plantations Berhad	Teluk Intan, Perak	• Deli Marihat • IRHO *pisiferas*
21.	Sarawak Plantation Agriculture Development Sdn. Bhd.	Miri, Sarawak	• MPOB Deli *duras* • MPOB AVROS
22.	NALFIN Planting Material Sdn. Bhd.	Teluk Intan, Perak	• MPOB Deli *duras* • MPOB AVROS

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References

Amblard P., Noiret J.M., Potier F., Kauame B. and Adon B. 1999. Comparative performance of interspecific hybrids and commercial *E. guineensis* material. In: Rajanaidu N. and Jalani B.S. (eds.) Proceedings of the seminar on worldwide performance of DXP oil palm planting materials, clones and interspecific hybrids. MPOB, Bangi. pp 128-143.

Barcelos, E., Amblard, P., Berthaud, J. and Seguin, M. 2002. Genetic diversity and relationship in American and African oil palm as revealed by RFLP and AFLP molecular markers. *Pesquisa Agropecuária Brasileira*. 37(8): 1105-1114

Beirnaert A. and Vanderweyen R. 1941. Contribution à l'étude génétique et biométrique des variétés d'*Elaeis guineensis* Jacq. Publications de l'Institut National pour l'Etude Agronomique du Congo Belge. Série scientifique n° 27.

Billotte N., Risterucci A.M., Barcelos E., Noyer J.L., Amblard P., Baurens F.C. 2001. Development, characterisation and across-taxa utility of oil palm (*Elaeis guineensis* Jacq.) microsattelite markers. Genome, 44(3): 413-435.

Chan K.W., Ong E.C., Tan K.S., Lee C.H. and Law I.H. 1986. The performance of oil palm genetic laboratory (OPGL) germplasm material. In: Proceedings of the International Society for Oil Palm Breeders (ISOPB). 26th to 27th March 1985. PORIM, Bangi.

Chin, C. F., Ho, W. K., Ong-Abdullah, M., Ooi, S. E., Mayes, S. and Namasivayam, P. 2010. Development of Biomarkers for Screening Oil Palm Tissue Culture Clones.

Corley R.H.V. and Tinker P.B. 2003. The oil palm. Fourth Editiom. Blackwell Publishing, Oxford.

Engelmann, F. 1991. Current development of cryopreservation for oil palm somatic embryos. pp. 1676-1680. In: Volume IV of the Proceedings of the XVIIIth International Refrigeration Congress. Montreal (Canada). 10-17 August 1991.

Ghesquiere A. 1985. Evolution of *Oryza longistaminata.* In: Rice genetics. International Rice Research Institute, Manila. p. 15-27.

Hartley C.W.S. 1988. The oil palm. Third edition. Longman, London. pp 761.

Heath R.G. 1958. Annual report of the Department of Agriculture for the year 1960. Federation of Malaya. Kuala Lumpur. Department of Agriculture Malaya.

Haddon A.V. and Tong Y.L. 1959. Oil palm and selection – A progress report. Malaysia Agriculture Journal. 42:124-156.

Idris A.S., Ariffin D., Swinburne T.R. and Watt T.A. 2000. The identity of *Ganoderma* species responsible for Basal Stem Rot Disease of oil palm in Malaysia – Pathogenity Test. MPOB TT no. 77B. p. 44.

Kushairi A. 1992. Prestasi Baka Kelapa Sawit *Dura* X *Pisifera* di Malaysia. M.S. Thesis. Universiti Kebangsaan Malaysia, Bangi.

Kushairi A. and Rajanaidu N. 2000. Chapter 3: breeding populations, seed production and nursery management. Advances in oil palm research. Vol. 1. MPOB, Bangi. p. 39-88.

Kushairi A., Mohd Din A., Rajanaidu N. 2011. Oil palm breeding and seed production. In: Mohd Basri W, Choo YM, Chan KW (eds) Further advances in oil palm research (2000–2010) MPOB, Bangi, pp. 47–101.

Maizura I., Rajanaidu N., Zakri A.H., Cheah S.C. 2006. Assessment of genetic diversity in oil palm (*Elaeis guineensis* Jacq). Using Restriction Fragment Length Polymorphism (RLFP). Genetic Research of Crop Evolution, 53: 187-195.

Mayes S., Jack P.L., Marshall D.F., Corley R.H.V. 1997. Construction of a RFLP genetic linkage map for oil palm (*Elaeis guineensis* Jacq). Genome, 40(1): 116-122.

Mohd Din A., Kushairi A., Maizura I., Isa Z.A., Noh A. and Rajanaidu N. 2005. MPOB Strategic plan for fast track breeding programmes. In: Proceedings of the 2005 National Seminar on Breeding and Clonal Technology. Seri Kembangan, Selangor, Malaysia. MPOB, Bangi. p. 43-53.

Moretzsohn M.C. 1995. Estudo de padrões electroforéticos e análise da variabilidade genetic de dendê (*Elaeis guineensis*), caiaué (*Elaeis oleifera*) e geracães F1 e RC1. M.S. Thesis. Universidade de São Paulo, Riberão Petro. São Paulo, Brazil.

Munier J. and Hardon J.J. 1976. Interspecific hybrids between *Elaeis guineenis* and *Elaeis oleifera.* In: Corley R.H.V., Hardon J.J. and Woods B.J. (eds.) Developments in Crop Science I. Oil palm reaserch. Elsevier Scientific Publishing Company. pp. 127-144.

Murphy D.J. 2007. Future prospects for oil palm in the 21st century: Biological and related challenges. European Journal of Lipid Science Technology. 109:296-306.

Ngoot-Chin T., Noorhariza M.Z., Rosli R., Eng-Ti L.L., Ithnin M., Cheah S.-C., Tan S.-G. and Singh R. 2010. SSR mining in oil palm EST database: application in oil palm germplasm diversity studies. Journal of Genetics. 89(2):135-145.

Noh A., Mohd Din A., Rajanaidu N. and Kushairi A. 2012. Performance of some *Elaeis oleifera*, interspecific hybrids and backcrosses. In: Proceeding of the International Society of Oil Palm Breeders (ISOPB). Hotel AR Salitre, Bogota. 21th – 24th September 2012.

Noorhariza M.Z., Rajinder S., Rozana R. and Ismanizan I. 2012. *Elaies oleifera* genomic-SSR markers: exploitation in oil palm germplasm diversity and cross-amplification in Arecaceae. International Journal of Molecular Science. 13:4069-4088.

Norziha A., Noh A., Fadila A.M., Zulkifli Y. and Mohd Din A. *Ganoderma* infection studies in selfed and inter-crossed Deli *Dura* progenies. 2012. In: Proceeding of the International Society of Oil Palm Breeders (ISOPB). Hotel AR Salitre, Bogota. 21th – 24th September 2012.

Nurniwalis A.W., Arif M.A. and Idris A.S. 2009. An amplified internal transcribes spacer region – a potential marker to distinguish *Ganoderma* and oil palm DNA preparations. In: Proceedings of the MPOB International Palm Oil Congress (PIPOC) 2009. pp. 1192-1204.

Purba A.R., Flori A., Baudouin L. and Harnon S. 2001. Prediction of oil palm (*Elaeis guineensis* Jacq.) agronomic performances using the best linear unbiased predictor (BLUP). Theory of Applied Genetics. 102:787-792.

Rajanaidu N., Mary N., Ong E.C. and Lee H.H. 1986. Sabah Breeding Programme (SBP). In: Proceedings of the International Society for Oil Palm Breeders (ISOPB). 26th to 27th March 1985. PORIM, Bangi.

Rajanaidu, N. 1994. MPOB Oil Palm Genebank: collection, evaluation, utilization and conservation of oil palm genetic resources. MPOB (Bangi). pp. 1-18.

Rajanaidu N., Kushairi A., Rafii M., Mohd Din A., Maizura I. And Jalani B.S. 2000. Oil palm breeding and genetic resources. Advances in oil palm research. p. 171-237.

Rajanaidu N. and Ainul M.M. 2013. Conservation of oil palm and coconut genetic resources. In: Normah M.N., Chin H.F. and Reed B.M.(eds). Conservation of tropical plant species. Springer, New York. pp. 189-212.

Seng T.-Y., Siti Hawa M.S., Chin C.-W., Ting N.-C., Singh R., Faridah Q.Z., Tan S.-G. and Sharifah S.R.S.A. 2011. Genetic linkage map of a high yielding FELDA Deli X Yangambi oil palm cross. Plos One. 6(11):e26593.

Soh A.C. 1994. Ranking parents by best linear unbiased prediction (BLUP). Euphytica. 76:13-21.

Soh A.C., Choo K.W., Yuk W.H. and Chieh W.C. 2010. Oil Palm. In: Vollman J. and Rajcan I. (eds.). Oil Crops. Springer, New York. pp. 333-367.

Turner P.D. 1981. Oil palm diseases and disorders. Oxford University Press. Kuala Lumpur.
Yusof B.. 2000. Techno-economic Aspects of Research and Development in the Malaysian Oil Palm Industry. In: Yusof B., Jalani B.S. and Chan K.W. (eds.) Advances in Oil Palm Research. MPOB, Bangi. pp. 1-18.
Yusof, B. 2007. Palm oil production through sustainable plantations. *European Journal of Lipid Science Technology.* 109:289-295.
Zulkifli Y., Maizura I. and Rajinder S. 2009. Genetic Diversity Study of *Elaeis guineensis* germplasm using EST-SSRs. In: Proceedings of The International Society for Oil Palm Breeders (ISOPB) Seminar. KLCC, Kuala Lumpur. 4-5 November 2009.