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DEVELOPMENT OF NEW OIL PALM CULTIVARS IN MALAYSIA

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ABSTRACT

At the beginning of the oil palm industry at the turn of the 20th century, commercial plantations utilised the thick-shell thin-mesocarp dura *planting materials. The breeds were unconsciously and informally selected from the 'best-looking' palms and fruits in the African palm groves or in subsequent decorative avenues elsewhere. Discovery of the single gene inheritance for shell thickness led to the use of the thinner-shell thicker oil-bearing mesocarp* dura *x* pisifera *(DxP) cultivated variety (cultivar). However, oil palm breeding populations had been derived from few ancestral palms, which hindered selection progress. The basic population of the maternal line in breeding programmes is almost exclusively the Deli* dura*. Improvements of* tenera/pisifera *paternal lines were mainly the AVROS, La Me and Yangambi populations. Malaysian oil palm breeders widely practiced the modified recurrent selection (MRS) in improvement programmes. Subsequent parental inbred lines developed in recurrent selections, crossed and progeny tested exploiting heterosis had boosted bunch and oil yields. The MRS allows incorporation of new genes into the parental lines; and coupled with the need to widen the genetic pool, wild* Elaeis guineensis *and* E. oleifera *germplasms were prospected in centres of origin and diversity in Africa and Latin America, respectively. Besides breeding for bunch and oil yields, secondary traits such as dwarfism, oil quality and phytonutrient contents are incorporated in developing PS series new varieties for niche purposes. A notable cultivar is PS1 characterised by short palm height. It takes more than 20 years from collection in the wild to the release of new cultivar. To speed up selection and release of cultivar, the preliminarily selected breeding materials are shared among local industry breeders for further breeding and improvements. In addition to quantitative genetics, further strides in cultivar development are supported by tissue culture, biotechnology and genomics. New varieties are registered based on the Test Guidelines for new, distinct, uniform and stable (DUS) of the International Union for the Protection of New Varieties of Plants (UPOV). Commercial production and sale of oil palm planting materials in Malaysia are regulated by law. Oil palm seed producers must be a registered company, financially sound and has a competent breeder. Seeds and seedlings for commercial sale must fulfill the requirements of Malaysian Standard MS157 (seeds) or MS2099 (clones) and subscribe to relevant certification schemes. Companies must obtain the license to produce, store, shipping and handling of the planting materials. Field performance of commercial oil palm planting materials are regularly evaluated in comparative trials.*

Keywords: breeding, selection, planting materials, improvement, cultivars, oil palm.

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INTRODUCTION

The Russian geneticist and agronomist, N. I. Vavilov who conceived the origin of the crops and geographical distribution of cultivated plants inspired breeders to collect and conserve the genetic resources of crops. According to Vavilov, there are two centres of origin for oil palm (Rajanaidu *et al*., 2017) *viz*. West African Centre for *Elaeis guineensis* and North-South American Centre for *E. oleifera*. At the beginning of the oil palm industry at the turn of the 20th century, commercial plantations utilised the

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thick-shell thin-mesocarp *dura* planting materials. The breeds were unconsciously and informally selected from the 'best-looking' palms and fruits in the African palm groves or in subsequent decorative avenues elsewhere. While acquiring open-pollinated seeds for avenue plantings, and the subsequent selection to supply seeds for more avenues, superior materials were unconsciously mass selected for several generations. The successful commercial planting of *E. guineensis* in 1917 in Tennamaran Estate, Kuala Selangor, Selangor has brought about substantial social and economic prosperity for Malaysia (Kushairi *et al.*, 2018).

Single Gene Inheritance

Discovery of the single gene, namely shell gene (SH), inheritance for shell thickness (Beirnaert and Vanderweyen, 1941) led to the use of the thinner-shell thicker oil-bearing mesocarp *dura* x *pisifera* (DxP) cultivar. The single gene gave a 3:1 phenotypic ratio for shell (present:absent) and 1:2:1 genotypic ratio for fruit form (homozygous SH+SH+ *dura*:heterozygous SH+SH- *tenera*: homozygous SH-SH- *pisifera*). Since 1960, commercial plantings were based on the *tenera* hybrids. An increase of more than 30% oil yield was realised with the switch from the *dura* to the *tenera* planting material. With the advent of the DxP planting materials, breeding programmes were diverted to select the *dura* and *pisifera* to generate the *tenera* seedlings (*Figure 1*).

However, oil palm breeding populations have been derived from few ancestral palms, which hindered selection progress. The history of oil palm breeding populations has been traced by a number of authors (Jagoe, 1952; Hardon and Thomas, 1968; Arasu and Rajanaidu, 1975; 1976; Rosenquist, 1986; Lubis, 1990).

Deli *Dura* Breeding Population

The oil palm industry in the East Asia owes its beginning to four *dura* seedlings introduced at the Bogor botanical garden, Indonesia in 1848 (Hartley, 1988). Seeds from Bogor were planted for esthetical purposes along avenues in Sumatra, notably in Deli, in 1870s (Kushairi, 1992). Materials from Sumatra were imported to Malaya (now known as Malaysia) in several occasions, but those planted along avenues in Rantau Panjang, Selangor in the 1910s mooted the oil palm industry in Malaysia. It should be realised that while acquiring open-pollinated seeds for avenue plantings and the subsequent selection to supply seeds for more avenues, superior materials were unconsciously mass selected for several generations. Formal breeding and selections were carried out since the 1920s in Indonesia at Marihat Baris Estate, and in Malaya at Elmina Estate and Serdang Experimental Station (Hardon and Thomas, 1968). After intense breeding and selections, these palms had become uniform in performance, yielding big bunches, good fruit characteristics with high mesocarp content. This population became known as Deli *dura* population. The Deli *dura* sub-populations in Malaysia (Serdang Avenue, Elmina, Dumpy E206, Ulu Remis and Johore Labis) are considered Breeding Populations of Restricted Origin (BPRO).

***Tenera*/*Pisifera* Breeding Populations**

Some common *tenera*/*pisifera* paternal lines were Yangambi, AVROS, Serdang 27B, NIFOR, La Me and derived *pisifera* but improvements mainly involved the AVROS, La Me and Yangambi populations. The *pisifera*s were generated from either *tenera* x *tenera* (TxT), *tenera* x *pisifera* (TxP) or *pisifera* x *pisifera* (PxP) crosses. The oil palm cultivated variety (cultivar) is

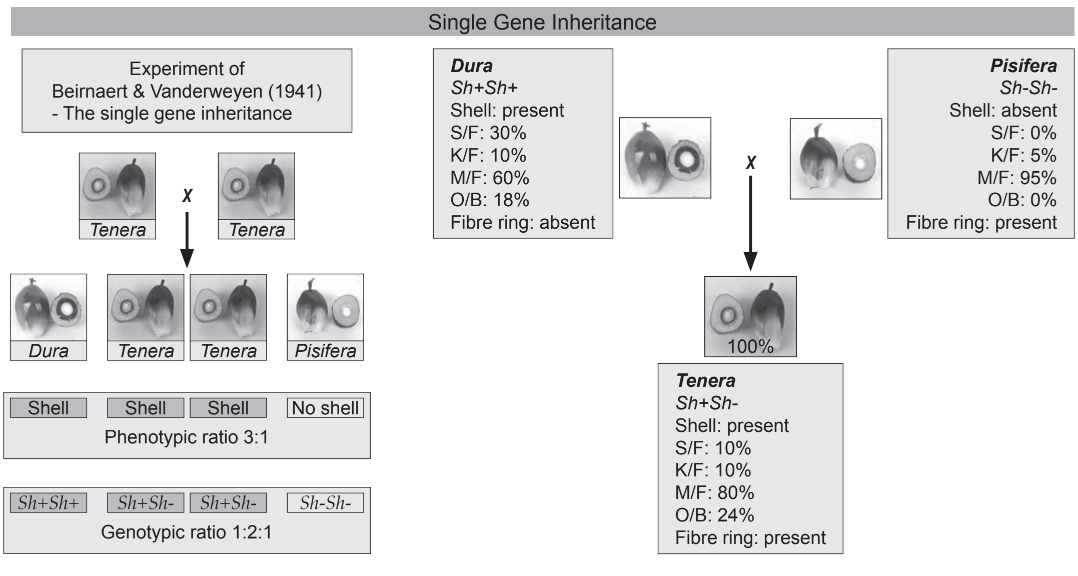

Figure 1. Discovery of single gene inheritance for shell and development of dura *x* pisifera *(DxP) cultivar.*

the common DxP planting material, which normally comprises the Deli *dura* x AVROS *pisifera* cross.

Improvement Programmes

A modified recurrent selection (MRS) plan is practised by a majority of Malaysian oil palm breeders (*Figure 2*). In the MRS method, selected *dura*s are crossed in various combinations using North Carolina Model I (NCM I) breeding design and the progenies planted in replicated trials. The NCM I mating design involves the crossing of a male (*pisifera*) with a set of 3-5 females (*dura*s). Several sets of crosses are made to make up a trial. After a minimum of four years of yield recording, and 3-5 bunches per palm had been analysed (determination of oil content), the palms were then selected for seed production and to generate the next cycle of *dura* mother palms. Yield over the first four years is highly correlated with yield from the 11^{th} to 16^{th} years (Blaak, 1965). Higher heritabilities are obtained from means of several years and a plateau value is approached for yield and bunch number after 3-4 years (Corley and Tinker, 2016). As *pisifera* palms are normally female sterile, there is no direct way to evaluate its worth. Thus, the yield potential and fruit qualities of the *pisifera*s are determined indirectly by progeny testing the selected *pisifera*s with elite *dura*s. Based on the *tenera* performance in the same DxP progeny test experiment, *pisifera*s that show good general combining ability (GCA) are selected for seed production. Introduction of new genes can be made into the breeding programme to increase the genetic variability (Hardon, 1970). The FFB and oil yields have been shown to increase (Lee and Toh, 1992).

Whilst, the *pisifera*s that give the best average performance in progeny trials are chosen, the *dura*s are selected in *dura* x *dura* (DxD) genetic blocks based on their own merits. *Dura* mother palms, on average, produce 6-8 bunches per year with 1000-2000 seeds per bunch, while the pollen of the *pisifera* palms can be used to pollinate many female inflorescences. Each male inflorescence of a mature palm produces about 30 g pollen, but harvesting of 100 g pollen is not uncommon. Thus, only a small number of individual *pisifera* palms (especially involving AVROS and some Yangambi) are the fathers of practically every oil palm that is grown commercially. The MRS involves inter-crossing among the selected parents and carrying progenies forward to the next cycle. Subsequent parental inbred lines developed in recurrent selections, crossed and progeny tested exploiting heterosis had boosted bunch and oil yields. The MRS allows incorporation of new genes into the parental lines.

Germplasm Collections

The oil palm has been footed on a narrow genetic base, the Deli *dura* being derived from four Bogor palms whereas the *pisifera*s from limited sources (AVROS, La Me and Yangambi). Coupled with the need to widen the genetic pool, wild *Elaeis guineensis*

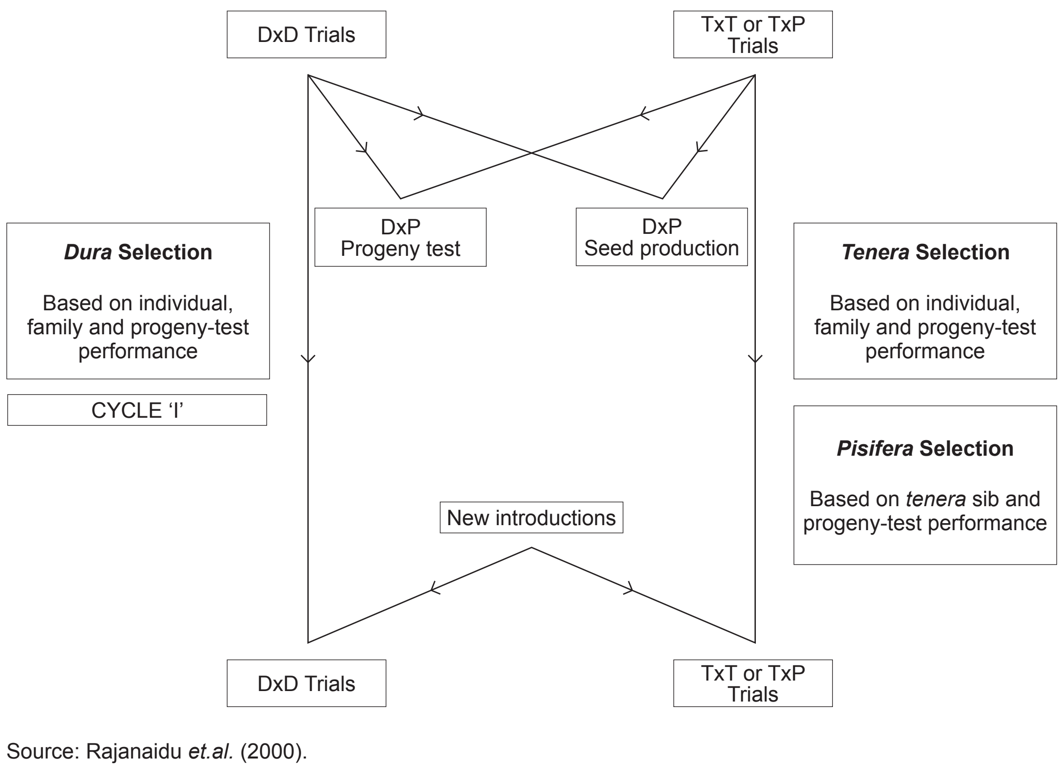

Figure 2. Modified recurrent selection scheme.

and *E. oleifera* germplasms were prospected in centres of origin and diversity in Africa and Latin America, respectively. The need for new materials of sufficient genetic variability to improve and safeguard the crop has been widely acknowledged for a long time (Hartley, 1988). The establishment of oil palm genetic resources as in any other crops, depends on the successful execution of major tasks - exploration, evaluation, improvement, utilisation and conservation.

Development of Secondary Traits

Besides breeding for bunch and oil yields, secondary traits such as dwarfism, oil quality and phytonutrient contents are incorporated in developing PS series (Rajanaidu *et al*., 2008; Noh *et al*., 2015) new varieties for niche purposes. Since 1992, 14 distinct genotypes have been distributed successfully to members of the industry.

The genotypes are the high yielding dwarf (PS1), high iodine value (PS2), large kernel (PS3), high carotene *E. oleifera* (PS4), thin-shelled *tenera*s (PS5), large fruit *dura*s (PS6), high bunch index (PS7), high vitamin E (PS8), exotic palm - *Bactris gasipaes* (PS9), long stalk (PS10), high carotene *E. guineensis* (PS11), high oleic acid (PS12), low lipase (PS13) and high protein kernel (PS14). These technologies were announced to the industry during MPOB annual Transfer of Technology (TOT) Seminars. Members of the industry are interested and adopted these technologies to use in their oil palm breeding and improvement programmes.

Selection

A notable cultivar is PS1 characterised by short palm height. It takes more than 20 years from collection in the wild to the release of new cultivar. Current DxP planting materials grow at 40-75 cm yr^{-1} and difficult to harvest after 20 years. One of the main priorities in oil palm is breeding for shorter palms. In 1982, extensive evaluation for yield, bunch traits, fatty acid composition, physiological parameters and vegetative characters were carried out. A number of genotypes were available to breed for dwarf palms. These elite palms were distributed to the members of the industry for progeny testing, introgression into the current breeding materials and to initiate new breeding lines for future seed production.

To speed up selection and release of cultivar, the preliminarily selected breeding materials were shared among local industry breeders for further breeding and improvements. After undergoing extensive progeny-testing, MPOB was also able to breed shorter planting materials (PS1.1) based on MPOB-Nigerian population 12.

Population 12 from MPOB-Nigerian germplasm was unique, being high yielding, short and compact. Some of the crosses produced high oil yield and 30% shorter than DxP control (Rajanaidu *et al*., 2013). Thus, it is easier to harvest and more amenable for mechanisation as well as reducing the production cost.

In addition to quantitative genetics, further strides in cultivar development are supported by tissue culture, biotechnology and genomics.

Clonal Seeds

Using tissue culture technology, clonal seeds can be produced. Clonal seeds are produced using parents with good specific combining ability (SCA). Some Malaysian breeding programmes are using self of the parents. Semi-clonal seeds are produced using either parent (*dura* clone x *pisifera*; *dura* x *pisifera* clone) as clones whereas bi-clonal seeds are produced using both parents (*dura* clone x *pisifera* clone) as clones.

Planting Materials

Hence, breeding programmes for production of oil palm planting materials involve production of DxP seeds (exploitation of general combining ability), clonal DxP seeds (exploitation of specific combining ability) and clones (individual palms). The duration from nursery to field take nine months for DxP and clones. Fast track approach for production of palms with special traits such as high bunch index, high vitamin E, high carotene, long stalk and low height increment has been pursued via cloning.

Genomics-guided Breeding

The revolution in life sciences signalled by genomics dramatically change the scale and scope of application in plant improvement. Application of genomics-based technologies is well suited for oil palm and this has led to huge investments in the area of plant genomics to help improve the speed and efficiency for producing new and improved planting materials. However, application of genomic-based technologies in plant breeding is not possible without systematic development of breeding programmes. In fact, systematic development of classical breeding programmes and precise phenotypic data collection forms the backbone of improvement using genomic-based approaches (Mohd Din *et al*., 2011).

With the sequence of the palm genome now completed by MPOB and others, it is worth turning our attention to the beginning of a new and exciting era of genomics-guided breeding. The use of the genome sequence in oil palm breeding has a high potential for success. Classical breeding, by family and recurrent selection, has a long selection cycle requiring many years and many hectares to advance elite palms. Marker-assisted selection, and even genomic selection, will greatly speed-up this process, as traits can be predicted long before they are scored.

Oil Palm Genome Programme

MPOB is the first organisation to sequence and release the genome sequence of both species of oil palm, namely *Elaeis guinnensis* and *Elaeis oleifera,* through a high impact and highly cited publication (Singh *et al*., 2013a). The identification of the SHELL gene linked to the formation of SHELL in the fruit was also identified (Singh *et al*., 2013b). Since then, the gene for fruit colour (Singh *et al*., 2014) and the epigenetic change that results in the abnormal mantled fruits had also been identified (Meilina *et al*., 2015). Diagnostic services to screen planting materials for these three traits had been developed. MPOB now strives to identify other traits that are also important to oil palm, such as yield, low height increment, disease resistance and fatty acid composition.

Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD) is a United Nations treaty formally adopted in Rio de Janeiro, Brazil in 1992. CBD recognises biological resources as sovereign rights of nations. Malaysia, being a party to CBD deposits equal portion of oil palm germplasm collection in the host country.

Plant Breeders Right (PBR) - Test Guidelines for New, Distinct, Uniform and Stable (DUS)

New varieties are registered based on the Test Guidelines for New, Distinct, Uniform and Stable of the International Union for the Protection of New Varieties of Plants (UPOV). The aim of the guidelines is to protect new oil palm varieties developed. Varieties are a form of intellectual rights and the developer/breeder should be given exclusivity to them to deter others from exploiting them. This gives them a chance to earn back their investment ploughed into research and to incentivise them to do more for the greater benefit of mankind. The Oil Palm DUS Test Guidelines were developed under the purview of the Department of Agriculture, Malaysia and officially published in February 2010 (Department of Agriculture Malaysia, 2010). Harmonised DUS TG of oil palm involves Malaysia (chair), Indonesia and Thailand under the East Asia Plant Variety Protection Forum (EAPVPF), Japan.

Malaysian Standard

The Department of Standards Malaysia (Standards Malaysia) is the national standardisation and accreditation body. Malaysian Standards are developed through consensus by committees which comprise of balanced representation of producers, users, consumers and others with relevant interests. To the greatest extent possible, Malaysian Standards are aligned to or are adoption of international standards. Approval of a standard as a Malaysian Standard is governed by the Standards of Malaysia Act 1996 (Act 549).

Seeds and seedlings for commercial sale must fulfill the requirements of Malaysian Standard MS157 - Oil Palm Seeds for Commercial Planting: Specification or MS2099 - Oil Palm Clones for Commercial Planting. Specification for Ortet Selection. Companies must obtain the license to produce, store, ship and handle the planting materials. Contamination by illegitimate pollen is a major hindrance to quality in seed production. Hence, extreme care must be exercised to prevent *dura* contamination, which is a crucial aspect for oil palm seed producers. The occurrence of thick-shelled *dura* in DxP crosses is due to illegitimate pollen. Thus, strict quality control measures should be followed during crossing to ensure the validity of the controlled pollination.

MS2099 was developed to ensure production authenticity for desired productivity and sustenance of the oil palm industry, where only high quality ramets, derived from high quality ortets, are produced. The MS includes requirements for ortet selection, guidelines on production practices, packaging and legal matters.

Malaysian Standards are reviewed periodically. The use of Malaysian Standards is voluntary except in so far as they are made mandatory by regulatory authorities by means of regulations, local by-laws or any other similar ways.

Legal Requirements

Producers of oil palm planting materials must obtain license to produce, store and move the planting materials. Producers must be a registered company, financially sound and have a competent breeder. Seeds, clones and seedlings for commercial sale must fulfill the requirements of Malaysian Standard MS157 (seeds) or MS2099 (clones). The seeds and clones shall in all aspects comply with the requirements of the legislations currently in force in Malaysia.

License for Oil Palm Seeds and Clones for Commercial Planting

This is a Related Legislation where Malaysian Standards are voluntary according to the Department of Standards Malaysia (Standards Malaysia). However, MS157 (seeds) and MS2099 (clones) are mandatory standards imposed by MPOB on producers regulated under the MPOB (Licensing) Regulations 2005. The industry is generally very well regulated and any revisions to improve the standards will immediately be imposed on producers.

Comparative Trials for Evaluation of Malaysian DxP

Field performance of commercial oil palm planting materials is regularly evaluated in comparative trials. MPOB, in cooperation with the industry, has carried out routine evaluation on the performance of Malaysian DxP to monitor the quality of planting materials produced locally (Kushairi, 1992; Kushairi *et al.*, 1994; 1997;1999; 2000; 2001; Isa *et al*., 2005; Mohd Din *et al*., 2014). To date, four rounds of evaluation have been completed.

CONCLUSION

Development of new oil palm cultivars owes a great deal to the work and dedication initiated by early breeders. Science, laws and regulations facilitate development and release of new cultivar and healthy growth of the industry.

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