



UNIVERSITI PUTRA MALAYSIA

**GENETICS OF THE DELI-AVROS BREEDING POPULATINS OF THE
OIL PALM (ELAEIS GULNEENSIS JACQ.)**

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**GENETICS OF THE DELI-AVROS BREEDING POPULATIONS
OF THE OIL PALM (*Elaeis guineensis* Jacq.)**

By

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Master of Agricultural
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GENETICS OF THE DELI-AVROS BREEDING POPULATIONS OF THE OIL PALM (*Elaeis guineensis* Jacq.)

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Chairman: Professor Ghizan Bin Saleh, Ph.D.

Faculty: Agriculture

This study was conducted to assess the phenotypic and genetic properties of two Deli-AVROS *dura* x *pisifera* breeding populations, which have gone through cycles of selection. The specific objectives for this study were: (i) to estimate phenotypic and genetic variances, additive and dominance genes effects and heritabilities (broad-sense and narrow-sense) for 20 traits measured in these two populations, (ii) to estimate phenotypic and genetic coefficients of variation for the traits concerned, (iii) to estimate phenotypic correlations among the traits concerned, and (iv) to estimate the general combining ability (GCA) of the male parents involved for the traits concerned.

The populations consisted of 33 *dura* x *pisifera* crosses, generated from controlled pollinations between female (*dura*) and male (*pisifera*) parents, following the North Carolina Mating Design I (NCM I). Population 1 with 15 crosses (5 males and 15 females) and Population 2 with 18 crosses (6 males and 18 females) had been grown in 1995, at two separate locations (Sg.Buloh and Nova Scotia estates, respectively) on coastal soils (Typic Tropaquept), in Consolidated Plantations Berhad, in



Peninsular Malaysia. These crosses had been previously planted in a Randomised Complete Block Design with three replications, with 12 palms (4x3) per plot, spaced at 8.8 metres in equilateral triangular pattern. Data on yield (fresh fruit bunch weight and bunch number), bunch and fruit components, vegetative traits and physiological traits were collected from these palms from January 2000 to December 2000.

Variability analysis revealed low phenotypic coefficients of variation (pcv) and low genetic coefficients of variation (gcv) for most of the traits measured in these two Deli-AVROS populations. Fresh fruit bunch yield/palm, bunch number/palm, average bunch weight, % fruit/bunch, % oil/bunch, % mesocarp/fruit, % oil/mesocarp, vegetative traits and physiological traits clearly showed low pcv and gcv values. However, % kernel/bunch, % kernel/fruit and % shell/fruit still maintained their moderate pcv and gcv values in both populations.

Relatively high dominance variances compared to their corresponding additive variances were recorded for fresh fruit bunch yield/palm, average bunch weight, % oil/bunch, fruit weight, and most vegetative and physiological traits in these two Deli-AVROS populations. However, higher additive variances compared to their dominance counterparts were shown for bunch number/palm and % mesocarp/fruit in both populations.

Broad-sense heritability estimates for most of the traits measured in these populations ranged from moderate to high, indicating that these traits were largely under genetic control and to a smaller extent influenced by the environmental factors.

Narrow-sense heritability estimates revealed that bunch number/palm, %



mesocarp/fruit and leaf area index were heritable, compared to traits viz. fresh fruit bunch, trunk girth and bunch dry matter which were less heritable in both populations.

Correlation analysis revealed that fresh fruit bunch yield/palm was positively correlated with bunch number/palm and average bunch weight in both populations. Among the bunch and fruit components, % fruit/bunch was positively correlated with % oil/bunch and % kernel/bunch, while % oil/bunch was significantly correlated with % mesocarp/fruit and % oil/mesocarp in both populations. Among the vegetative traits, petiole cross section was positively correlated with rachis length in both populations.

This study has identified AVROS *pisifera* parents with good general combining ability (GCA) for fresh fruit bunch yield/palm, % oil/bunch, % kernel/bunch and bunch index.

The two Deli-AVROS breeding populations had low phenotypic and genetic variability for most of the traits measured. An effort has to be taken to broaden their genetic variability by introgression of genes from other germplasm sources.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains Pertanian

**GENETIK PADA POPULASI BIAKBAKA KELAPA SAWIT
(*Elaeis guineensis* Jacq.) DELI-AVROS**

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Kajian ini dilaksanakan untuk menilai sifat fenotip dan sifat genotip pada dua populasi biakbaka *dura x pisifera* Deli-AVROS, yang telah melalui beberapa pusingan pemilihan. Objektif khusus kajian ini pula adalah untuk: (i) menganggarkan varians fenotip dan varians genetik, kesan gen aditif dan gen dominan, dan menganggarkan nilai keboleherisan (bentuk luas dan sempit) terhadap dua puluh ciri yang diukur dalam dua populasi ini, (ii) menganggarkan pekali varians fenotip dan pekali varians genetik untuk ciri-ciri berkenaan, (iii) menganggarkan pekali korelasi di antara ciri-ciri tersebut, dan (iv) menganggarkan keupayaan bergabung am (GCA) pada induk-induk jantan untuk ciri-ciri berkenaan.

Populasi terdiri daripada 33 kacukan *dura x pisifera*, di hasilkan menerusi pedebungan berbantu diantara induk betina (*dura*) dan jantan (*pisifera*) mengikut Rekabentuk Kacukan 'North Carolina' Design I (NCM 1). Populasi 1 mengandungi 15 kacukan (5 jantan dan 15 betina) dan Populasi 2 mengandungi 18 kacukan (6 jantan dan 18 betina), telah ditanam pada tahun 1995, di dua lokasi (Ladang Sungai Buloh dan Ladang Nova Scotia) di tanah lanar pantai (Typic Tropaquept), di syarikat

Consolidated Plantations Berhad, di Semenanjung Malaysia. Kacukan *dura x pisifera* ini dahulunya ditanam dalam Rekabentuk Blok Penuh Rawak dengan tiga replikasi. Setiap plot mengandungi 12 pokok (4x3), dengan jarak tanaman 8.8 meter secara tiga segi sama. Data hasil (tandan buah segar dan bilangan tandan), komponen tandan dan buah, ciri tampang dan fisiologi telah diambil dari bulan Januari 2000 hingga bulan Disember 2000.

Analisis kepelbagaian menunjukkan pekali variasi fenotip (pcv) dan pekali variasi genetik (gcv) yang rendah untuk kebanyakan ciri yang diukur di dalam kedua-dua populasi Deli-AVROS tersebut. Hasil tandan buah segar/pokok, bilangan tandan/pokok, purata berat tandan, % buah/tandan, % minyak/tandan, % sabut/tandan, % minyak/sabut, ciri tampang dan fisiologi dengan jelas telah menunjukkan nilai pcv and gcv yang rendah. Walau bagaimanapun, % isirong/tandan, % isirong/buah dan % tempurung/buah masih mengekalkan nilai pcv dan gcv yang sederhana dalam kedua-dua populasi.

Secara relatifnya, varians dominan yang melebihi varians aditif telah direkodkan untuk hasil tandan buah segar/pokok, purata berat tandan, % minyak/tandan, berat buah dan kebanyakan ciri tampang dan fisiologi dalam kedua-dua populasi Deli-AVROS ini. Walau bagaimanapun, varians aditif yang melebihi varians dominan telah ditunjukkan untuk ciri bilangan tandan/pokok dan % sabut/buah dalam kedua-dua populasi.

Anggaran kebolehwarisan luas untuk kebanyakan ciri yang diukur dalam populasi ini berada di antara sederhana hingga tinggi, menunjukkan bahawa ciri-ciri tersebut

adalah di bawah kawalan genetik, manakala sebahagian kecilnya dipengaruhi oleh persekitaran. Anggaran kebolehwarisan sempit menunjukkan bilangan tandan/pokok, % sabut/buah dan indeks luas daun mempunyai kebolehwarisan yang tinggi, berbanding dengan tandan buah segar/pokok, garis pusat batang pokok dan berat tandan kering yang mempunyai kebolehwarisan yang rendah di kedua-dua populasi ini.

Analisis korelasi menunjukkan hasil tandan buah segar/pokok mempunyai korelasi positif dengan bilangan tandan/pokok dan purata berat tandan dalam kedua-dua populasi. Di kalangan komposisi tandan dan buah, % buah/tandan mempunyai korelasi positif dengan % minyak/tandan dan % isirong/tandan. Sementara itu, % minyak/tandan mempunyai korelasi positif dengan % sabut/buah dan % minyak/sabut dalam kedua-dua populasi tersebut. Di kalangan ciri tampang pula, luas muka keratan tangkai pelepah mempunyai korelasi positif dengan panjang tulang pelepah dalam kedua-dua populasi.

Dari kajian ini, induk pisifera yang mempunyai GCA yang baik untuk hasil tandan buah segar/pokok, % minyak/tandan, % isirong/tandan dan indeks tandan telah dikenalpasti.

Kedua-dua populasi Deli-AVROS ini mempunyai kepelbagaian fenotip dan genotip yang rendah untuk kebanyakan ciri yang diukur. Satu usaha perlu dilakukan untuk meluaskan kepelbagaian genetik mereka menerusi introgresi gen-gen dari sumber bahan baka sawit yang lain.

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LIST OF ABBREVIATIONS

MPOB	Malaysian Palm Oil Board
AVROS	Algemene Vereniging van Rubber-planters ten Oostkust van Sumatra (now known as Balai Penelitian Pekebun medan)
NIFOR	Nigerian Institut for Oil Palm Research
RISPA	Research Institute of the Sumatran Planters Association
OPRS	Oil Palm Research Station, Banting Selangor (Golden Hope Group)
OPGL	Oil Palm Genetic Laboratory
NCM I	North Carolina Mating Design I
PCV	Phenotypic coefficient of variation
GCV	Genetic coefficient of variation
h^2_B	Broad-sense heritability
h^2_N	Narrow-sense heritability
GCA	General combining ability
r	Correlation coefficient
df	Degree of freedom
MS	Mean squares
EMS	Expected mean squares
S.E	Standard error
Cov	Covariance



CHAPTER 1

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) exists in wild and semi-wild forms in Africa. A strong evidence revealed that, its origin was from Africa (Zeven, 1965). Presently, this crop is being cultivated in three main regions at the equatorial tropics, namely Africa, South-East Asia and South America. Its introduction into South-East Asia was well documented by Hunger (1924), that the first four oil palm seedlings (two from Hortus at Amsterdam and two from Mauritius) were planted in the Botanical Garden of Bogor, Indonesia, in 1848. From it, open pollinated Deli *dura* seeds were distributed to several parts in Sumatra for avenue plantings, and later become the source of planting material for new oil palm plantations in early 1900's (Hartley, 1977). Open pollinated seeds of Deli *dura* palms from these ornamental avenues and other plantings in Sumatra were introduced into Malaysia in 1911, as a source of planting material for commercial plantings. It was believed that the first estate in Malaysia to obtain this material was Tennamaram estate, via Rantau Panjang estate in Sumatra (Hartley, 1977).

The first large scale commercial oil palm plantings in Indonesia and Malaysia were started in 1920's, where the Deli *dura* open pollinated seeds were used as their planting material (Hartley, 1977). However, since 1960's, the hybrid called *tenera* or *dura* x *pisifera* planting material has been introduced to replace the Deli *dura* in commercial plantings, following the discovery of the *tenera* type palms (Beirnaert and Vanderwegen, 1941). This material is produced through controlled pollination



between selected *dura* (female) and selected *pisifera* (male) palms. Currently, the Deli *dura* is widely used as a common source of mother palms to produce the *tenera* materials by most of the oil palm breeding stations in Malaysia. The commercial *tenera* or *dura* x *pisifera* material can produce on the average, five to six tonnes of mesocarp oil per hectare annually, as an equivalent to 25-30 tonnes of fresh fruit bunch per hectare per year, with oil extraction rate of 20% (Mohd Haniff, 2000). It also produces 1.5 to 1.8 tonnes of kernel or 0.75 to 0.90 tonnes of kernel oil per hectare.

The oil palm is a perennial crop, with the life span of between 25 to 30 years. Its fresh fruit bunch production initiated at two and half to three years after field plantings. Currently, over 3.0 million hectares of land areas in Malaysia are cultivated with this crop. In 1999, Malaysia had produced 10.6 million tonnes of crude palm oil and 1.3 million tonnes of crude palm kernel oil. Of these, 8.9 million tonnes of crude palm oil and 0.6 millions tonnes of kernel oil were exported (MPOB, 2000). World production of crude palm oil was 23.3 million tonnes in 1999, an increased of 3.6 million tonnes or 21.3% compared to the previous year's production. In the same year, production of world oil and fats was increased by 6.1 million tonnes or 6.0% to 108.8 million tonnes. This expansion was largely due to the sizeable increase in the production of palm, rapeseed, sunflower and soybean oils (MPOB, 2000). It was projected that, by the year 2020, the world production of oils and fats might increase to 174 million tonnes. Of this, oil palm contribution to oil production was estimated to be at 35 million tonnes (Jailani, 1998). With this expectation, palm oil shall be a dominant edible oil in the world.



The palm oil and palm kernel oil produced by the oil palm are primarily used in the manufacture of margarine, compound cooking fat and soap (Hartley, 1977). Other non-food uses include the production of oleochemical products such as fatty acids, fatty esters, fatty alcohol, fatty nitrogens and glycerol (Rajanaidu et al., 2000). Besides these, recently some interest has been shown to convert the palm biomass, mainly lignocellulosic, into fibre and paper, but its production in commercial scale has yet to materialise.

The oil palm, unlike cash crop such as maize, requires at least 8 to 10 years to complete its first breeding cycle. Although it takes a longer duration to obtain progress and improvement in fresh fruit bunch yield, oil yield and other traits in oil palm through breeding programmes, it is necessary to obtain the basic knowledge on variability and heritability estimates for essential traits from genetic studies on the oil palm populations. This information will assist in designing an efficient breeding plan for future selection and improvement programmes for an oil palm population.

In view of this, the present study was conducted with the general objective of assessing the phenotypic and genetic properties of two Deli-AVROS breeding populations which have gone through several cycles of selection. The specific objectives of the study were: (1) to estimate phenotypic variance, genetic variance, additive and non-additive gene effects, broad-sense heritability and narrow-sense heritability for 20 traits assessed in these populations, (2) to estimate phenotypic and genotypic coefficients of variation for the traits concerned, (3) to estimate phenotypic correlation coefficients among the traits, and (4) to estimate the general combining ability (GCA) of the male parents involved for the traits concerned.

CHAPTER 2

LITERATURE REVIEW

2.1 Growth and Morphology of the Oil Palm

Corley et al. (1976) have been able to describe in details the vegetative parts in the oil palm. The leaf of the oil palm consists of leaflets (each with a lamina and midrib), a central rachis to which the leaflets are attached, a petiole (the part of the leaf stalk between the lowest leaflets and the trunk) and leaf sheath, whilst its trunk consists of a mass of discrete vascular bundles embedded in parenchymatous tissue with no secondary thickening occurring and grows to its full width shortly below the apex. The flowers are borne on separate male and female inflorescence, and termed *monoecious*. The inflorescences are attached within the leaf axils, with one inflorescence per leaf axil.

The oil palm root is adventitious, where it is further divided into primary roots (6 mm to 10 mm in diameter) which arise from the trunk base, secondary roots (2 mm to 4 mm in diameter), tertiary roots (0.7 mm to 1.2 mm in diameter), and quaternary roots (0.1 mm to 0.3 mm in diameter and 1.0 mm to 4 mm in length) which are always assumed to be the main absorbing roots (Tinker, 1976).

The oil palm bunch consists of fruits (outer fruits, inner fruits with less pigment, parthenocarpic fruits and some undeveloped non-oil-bearing 'infertile' fruits), spikelets and a stalk. The oil palm fruit is a sessile drupe, where the outer pulp or mesocarp provides palm oil or mesocarp oil, and within the mesocarp lays a

hard-shelled nut which contains the kernel that provides two commercial products, the palm kernel oil which has a similar composition to the coconut oil, and the residual called palm kernel cake used as livestock feed (Hartley, 1977). Based on the shell thickness of the nut, the oil palm can be grouped into three types, *viz. dura* (thick shell without fiber ring), *tenera* (intermediate shell thickness with fiber ring) and *pisifera* (very thin shell, with or without kernel).

2.2 Progress of Oil Palm Breeding in Malaysia

In Malaysia, the first yield assessment and selection in oil palm (Deli *dura*) was carried out by Jack and Jagoe in 1930's (Hartley, 1977). Based on available information, Hartley (1977) stated that, after a few rounds of selection, there was little progress in fresh fruit bunch yield within Deli *dura* populations. This was due to their narrow genetic base, as they were originated from limited number of parents. Because of this, from 1930 to 1940, the Department of Agriculture has made importation of *tenera* materials from Africa (seeds and pollen), with the objective of widening the genetic variability of the Deli palms through introgression. As a result, by 1960 to 1970, the *tenera* planting material has been introduced in commercial plantings to replace the Deli *dura* material. This new material had much better in oil yield, with an estimated 10% higher than that of the *dura* material (Soh, 1983). Later, studies were conducted to assess yield improvements within *tenera* materials. Lee and Yeow (1985) found that, the improvement in yield of *tenera* materials planted in 1979 over those in 1960 was 3.5 tonne/ha/yr, recorded in Golden Hope Plantations Berhad. The % oil/bunch was increased from 23.5% (1960 plantings) to 25.8% (1979 plantings), an increment of 2%. This improvement was due to selection and breeding



work. Further improvement was seen to be difficult, because of low genetic variability. Owing to this fact, in 1973, Malaysian Agricultural Research and Development Institute (MARDI) had imported the wild open pollinated oil palm seeds from Nigeria to widen the genetic base of oil palm germplasm in the country (Rajanaidu and Rao, 1987). This was followed by prospecting of wild oil palm materials by Malaysian Palm Oil Board (MPOB) from other countries, namely Cameroon (1984), Zaire (1984), Tanzania (1986), Madagascar (1986), Angola (1991), Senegal (1993), Gambia (1993), Sierra Leone (1994) and Guinea (1994) (Rajanaidu, 1994). Evaluation of these materials are still being carried out by MPOB. After one cycle of evaluation on the Nigerian germplasm material, MPOB has identified some families with outstanding traits for fresh fruit bunch, oil yield or % oil/bunch, iodine value, kernel content and dwarfness (Rajanaidu, 1984). Pollen from these palms are being introgressed with established oil palm breeding materials (Deli *dura*, AVROS, Ekona and Calabar) by private breeding stations in the country, to broaden genetic variability in local breeding materials, as an effort to open up more areas for future selection and improvement. Besides this, MPOB has started building up its capability and capacity to carry out transgenic technology to introduce foreign genes into oil palm, to develop new types of planting materials (Rajanaidu et al., 1988).

In reality, the progress of oil palm breeding in Malaysia is considered slow, due to the narrow genetic base of the initial materials used in breeding work, as they were originated from limited number of parents, and also due to the nature of this crop, which requires a longer duration to complete a breeding and selection cycle, being a perennial. Through introgression of foreign genes, which is currently being carried

