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QUANTITATIVE GENETICS ANALYSIS AND PROGENY TESTING OF DELI DURA × SERDANG-AVROS *PISIFERA* FOR LONG STALK CHARACTERISTIC

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By

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The oil palm plantations are a labour-intensive industry and to reduce dependency on labour, work process improvement by adopting technologies and machines need to be done. However, there are no harvesting machine that is as cost effective, efficient and dependable as the human harvester. Longer bunch stalk was believed to ease harvesting the fresh fruit bunch (FFB) either by machine or by manual. It eases the harvesting process as there are gaps between the bunch and the petiole bases. A total of nine oil palm Deli *dura* × Serdang-AVROS *pisifera* (D×P) derived from the North Carolina Mating Design 1 (NCM1) were evaluated at Dusun Durian Estate, Banting, Selangor. The Deli *dura* in this study originated from Banting *dura* and were crossed with Serdang-AVROS *pisifera.* The materials were evaluated for yield and yield components, bunch quality, vegetative traits and bunch stalk length. The data were collected from April 2009 to March 2018. The main objective of this study was to identify bunch stalk length of more than 25 cm in Deli *dura* × Serdang-AVROS *pisifera* progeny and Serdang-AVROS *pisifera* male parent to be commercialized and used as planting material. The specific objectives of the study were to evaluate the performance of Deli *dura* × Serdang-AVROS *pisifera* progenies for yield and yield components, bunch quality, vegetative traits and bunch stalk length, to evaluate general combining ability (GCA) of parents for stalk length trait through progeny testing, to estimate genetic variability and heritability, to assess correlation between stalk length with traits of economic importance and to analyse path coefficient analysis between all the traits studied with oil yield. Analysis of variance (ANOVA) in full-sib families showed that significant amount of genetic variability exists among Deli *dura* × Serdang-AVROS *pisifera* progenies yield and yield components, bunch quality, vegetative traits and bunch stalk length. The genetic variability is important for a successful breeding and selection. The yield and bunch quality performance of Deli *dura* × Serdang-AVROS *pisifera* progenies were comparable with Deli *dura* × AVROS *pisifera* planted in the same trial as control. ANOVA showed that the *Pisifera* item in the half-sib families was significant to almost all traits except mean fruit weight

(MFW), oil-to-dry mesocarp (%O/DM) and oil-to-wet mesocarp (%O/WM). The result was expected as male parents are coming from the combination of two male populations; Serdang and AVROS. Mean stalk length of the nine progenies studied were ranged from 20.66 to 26.93 cm. Progeny BM 4340, BM 4344 and BM 4351 had bunch stalk length means of more than 25 cm. From 445 palms measured, 42 individual palms had bunch stalk length more than 30 cm. Broad-sense heritability estimates for average bunch weight, mesocarp-to-fruit (%M/F), shell-to-fruit (%S/F), kernel-to-fruit (%K/F), kernel-to-bunch (%K/B), rachis length and stalk length were moderate in Deli *dura* × Serdang-AVROS *pisifera*, suggesting greater genetic control and small environmental influence. Low narrow-sense heritability estimates were observed in yield and yield components with $h^2_{n(p)}$ of 0-8.28% and $h^2_{n(d)}$ of 0.53-41.67%. Narrow-sense heritability estimates for bunch quality were also low with $h^2_{n(p)}$ of 0-45.94% and $h^2_{n(d)}$ of 1.68-24.34%. Higher narrow-sense heritability estimates were observed in vegetative traits for *dura* or maternal side with $h^2_{n(d)}$ of 31.77-101.06%. Correlation between bunch stalk length and all traits were also observed in this study. Bunch stalk length correlated positively with average bunch weight, mesocarp-to-fruit and rachis length. The study suggested that, selecting for long stalk length will resulting in heavier bunch, thicker mesocarp and longer rachis length. This study has identified male parent, BM 2436/9 as the best Serdang-AVROS *pisifera* with high GCA for fresh fruit bunch yield, bunch number, average bunch weight, mesocarp-to-fruit (%M/F), oil-to-bunch (%O/B), oil yield per palm (O/P) and oil per hectares (O/Ha). The *pisifera*, BM2455/7 was the best general combiner for palm height and stalk length.

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

ANALISA GENETIK KUANTITATIF DAN PENGUJIAN PROGENI KE ATAS DELI *DURA* × SERDANG-AVROS *PISIFERA* UNTUK CIRI PANJANG TANGKAI

Oleh

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Perladangan kelapa sawit merupakan sebuah industri yang menggunakan pekerja yang ramai dan untuk mengurangkan kebergantungan terhadap pekerja, penambahbaikan dalam proses kerja dengan mengadaptasi teknologi dan mesin perlu dilaksanakan. Tetapi, tiada mesin menuai buah sawit yang setara seperti seorang penuai buah sawit dari segi penjimatan kos, tahap efisien dan diyakini sehingga ke hari ini. Tangkai buah sawit yang lebih panjang dipercayai dapat memudahkan proses menuai buah samaada dengan menggunakan mesin atau dengan cara manual. Ia memudahkan proses penuaian buah kerana terdapat ruang antara tandan buah sawit dengan pelepah daun sawit. Sembilan progeni Deli *dura* × Serdang-AVROS *pisifera* (D×P) yang dihasilkan daripada kacukan rekabentuk pengawanan Carolina Utara 1 (NCM1) telah ditanam di Ladang Dusun Durian, Banting, Selangor. Sumber Deli *dura* yang digunakan berasal daripada Banting *dura* dan dikacukkan dengan Serdang-AVROS *pisifera*. Material ini dinilai dari segi hasil dan komponen hasil, kualiti buah, ciri tampang dan panjang tangkai tandan. Pengumpulan data tersebut adalah dari April 2009 sehingga Mac 2018. Objektif utama kajian ini dilaksanakan untuk mengenalpasti pokok sawit yang melebihi 25 cm di dalam progeni Deli *dura* × Serdang-AVROS *pisifera* dan Serdang-AVROS *pisifera* induk jantan. Objektif khusus adalah untuk menilai prestasi progeni Deli *dura* × Serdang-AVROS *pisifera* bagi hasil dan komponen hasil, kualiti buah, ciri tampang dan panjang tangkai tandan, mengangar keupayaan bergabung am (GCA) pada induk-induk jantan untuk ciri panjang tangkai melalui pengujian progeni, menganggar genetik varians dan nilai kebolehwarisan, menilai pekali korelasi antara panjang tangkai buah dengan ciri ekonomi yang dikehendaki dan mengkaji analisis pekali laluan antara ciri-ciri yang dikaji dengan hasil minyak.Analisa varians progeni penuh sib menunjukkan terdapat variasi genetik di kalangan progeni Deli *dura* × Serdang-AVROS *pisifera* bagi hasil dan komponen hasil, kualiti buah, ciri tampang dan panjang tangkai tandan. Kewujudan variasi genetik penting untuk kejayaan pembiakbakaan dan pemilihan. Prestasi hasil dan kualiti buah progeni Deli *dura* × Serdang-AVROS *pisifera* adalah setanding dengan progeni Deli *dura* ×

AVROS *pisifera* yang ditanam sebagai progeni kawalan. Analisa varians untuk famili separuh sib menunjukkan bahawa sumber *Pisifera* mempunyai perbezaan bererti untuk hampir kesemua ciri kecuali purata berat buah (MFW), minyak ke mesokarpa kering (%O/WM) dan minyak ke mesokarpa segar (%O/WM). Keputusan ini sudah dijangkakan kerana induk jantan yang digunakan dalam kajian ini adalah hasil kacukan dua populasi iaitu Serdang dan AVROS. Purata panjang tangkai tandan untuk sembilan progeni yang dikaji adalah berjulat antara 20.66 ke 26.93 cm. Progeni BM 4340, BM 4344 dan BM 4351 mempunyai purata panjang tangkai tandan melebihi 25 cm. Daripada 445 pokok kelapa sawit yang dicerap, 42 pokok mempunyai panjang tangkai melebihi 30 cm. Analisa keterwarisan luas bagi purata berat tandan (ABW), mesokarpa ke buah (%M/F), tempurung ke buah (%S/F), isirung ke buah (%K/F), isirung ke tandan (%K/B), panjang pelepah dan panjang tangkai sawit berada di tahap sederhana bagi Deli *dura* × Serdang-AVROS *pisifera* yang menunjukkan ciri-ciri tersebut di bawah kawalan genetik dan hanya sebahagian kecil dipengaruhi persekitaran. Anggaran nilai keterwarisan sempit yang rendah ditunjukkan dalam ciri hasil dan komponen hasil dengan nilai $h^2_{n(p)}$ berjulat antara 0 - 8.28% dan $h^2_{n(d)}$ berjulat antara 0.53 - 41.67%. Anggaran keterwarisan sempit bagi komponen kualiti tandan juga adalah rendah dengan $h^2_{n(p)}$ berjulat antara 0 - 45.94% dan $h^2_{n(d)}$ berjulat antara1.68 - 24.34%. Angaran keterwarisan sempit yang lebih tinggi didapati di dalam ciri tampang bagi induk betina berjulat antara 31.77 - 101.06%. Panjang tangkai tandan didapati mempunyai korelasi positif dengan purata berat tandan (ABW), mesokarpa ke buah (%M/F) dan panjang pelepah. Ini menunjukkan bahawa dengan memilih tandan yang lebih panjang akan memberikan tandan yang lebih berat, mesokarpa yang lebih tebal dan pelepah yang lebih panjang. Kajian ini telah mengenalpasti induk jantan, BM2436/9 sebagai Serdang-AVROS *pisifera* yang terbaik kerana mempunyai GCA yang tinggi untuk hasil berat tandan segar (FFB), jumlah tandan (BNO), purata berat tandan (ABW), mesokarpa ke buah (%M/F), minyak ke tandan (%O/B), hasil minyak per pokok (O/P) dan hasil minyak per hektar (O/Ha). *Pisifera* BM2455/7 pula mempunyai GCA yang tinggi untuk ketinggian pokok dan panjang tangkai tandan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF SYMBOL AND ABBREVIATIONS

ABW	Average bunch weight
ANOVA	Analysis of variance
AVROS	Algemene Vereniging van Rubber-planters ten Oostkust van Sumatra (now known as Balai Penelitian Pekebun medan)
BNO	Bunch number
bunches palm^{-1} yr^{-1}	Bunches per palm per year
Cm	Centimeter
cm yr^{-1}	Centimeter per year
°C	Degree Celsius
d.f.	Degree of freedom
D×P	*Dura* × *pisifera*
et al.	*et alia*
EMS	Expected mean squares
F/B	Fruit to bunch
FFA	Free fatty acid
FFB	Fresh fruit bunch
F_1	First filial generation
GCA	General combining ability
G	Gram
h^2_B	Broad – sense heritability
h^2_n	Narrow – sense heritability
INEAC	Institut National pour l'Etude Agronomique du Congo Belge
IRHO	Institut de la Recherche pour les Huiles et Oleagineux
JL	Johore Labis
K/B	Kernel to bunch
K/F	Kernel to fruit
kg bunch^{-1}	Kilogram per bunch
kg palm-^{1}yr^{-1}	Kilogram per palm per year
M/F	Mesocarp to fruit

MPOB	Malaysian Palm Oil Board
MS	Mean squares
Min	Minute
NCM 1	North Carolina Mating Design I
NIFOR	Nigerian Institute for Oil Palm Research
no $palm^{-1}yr^{-1}$	Number per palm per year
O/B	Oil to bunch
O/DM	Oil to dry mesocarp
O/HA	Oil yield per hectares
O/P	Oil yield per palm
OPGL	Oil Palm Genetic Laboratory
R	Correlation coefficient
SIRIM	Standard and Industrial Research Institute of Malaysia
S/F	Shell to fruit
SL	bunch stalk length
Socfin	Societe Financiere de Cauotchouces
t ha^{-1} yr^{-1}	Tonnes per hectares per year
PHT	Palm height
Ppm	Parts per million
UR	Ulu Remis
σ^2	Variance

CHAPTER 1

INTRODUCTION

1.1 Background to the study

Elaies guineensis Jacq. or commonly known as oil palm grows in a wild, semi-wild and cultivated state in the three land areas within ±10˚latitude of the equator namely Africa, South-East Asia and America (Hartley, 1988). It is believed that oil palm is originated from Africa (Zeven, 1964; Hartley, 1988; Corley and Tinker, 2003). Oil palm has been widely cultivated in South-East Asia since it was first introduced in 1848. The first four palms seedlings were received directly or indirectly in the form of seeds from the island of Bourbon (La Réunion) or Mauritius through Amsterdam (Jagoe, 1952a). The palms were planted in the botanical garden at Bogor, Indonesia. Offspring from the open pollination of the four palms which later known as Deli *dura* were distributed to several areas in Sumatera for avenue plantings. Value of oil palm as oil crop was recognised after that and commercial planting were established in between 1911 to 1920 in Sumatera and Peninsular Malaysia. Tennamaram estate in Selangor was believed to be the first estate in Malaysia to obtain the material in 1911 from Rantau Panjang estate in Sumatera (Hartley, 1977). In 1960's, Deli *dura* were replaced by hybrid called *tenera* as commercial planting material based on discovery of *tenera* type palms (Beirnaert and Vanderweyen, 1941). Commercial *tenera* material is produced through controlled pollination of selected *dura* as female parent and selected *pisifera* as male parent. Currently Deli *dura* is the common source of female parent used to produce *tenera* as commercial planting material in Malaysia.

Oil palm has become one of the most important commodity crops for Malaysia. Total planted area under oil palm in Malaysia has expanded rapidly since the first introduction of oil palm to Malaysia in 1917. Although the area expansion has appeared to grow at slower annual growth rates during the millennium due to land constraint in the country, the total planted area as at 2017 was 5.8 million hectares (Malaysian Palm Oil Board, 2018).

1.2 Problem statement

The oil palm plantations are a labour-intensive industry. There are five main job categories in oil palm estate, i.e, general mandore, harvesting mandore, fresh fruit bunch (FFB) harvester and collector, field worker and general worker. It was estimated that the plantations worker shortage was about 39,000 workers and majority were for FFB harvester and collector (Nambiappan *et al.*, 2018).

The dependency of the industry to foreign labour has become a serious issue in the country. The income of the oil palm producers can be affected by the heavy dependence on foreign labour especially during festive season (Ayat and Faizah, 2009). In Sabah, the foreign workers will go back to Indonesia for festive holidays and their absence will reduce the harvesting frequency. Sometimes, some of them will not come back because they get the same jobs with similar wages in Indonesia (Mamat, 2010). The number of Indonesian workers applying for jobs in Malaysia's palm oil sector plummeted to only 38,000 in 2013 compared to more than 120,000 in the previous two years (Raghu, 2014). The frequent abrupt changes in foreign labour policy and inconsistent application processes has also resulted in several periods of severe labour shortage (Khoo and Chandramohan, 2002).

It is clear that to reduce dependency on labour, work process innovation by adopting technologies and machines need to be done. Introduction and adoption of various mechanization methods has been able to reduce land to labour ratio. The land to labour ratio in the 1980s was 1:6 to 1:7. The ideal land to labour ratio for oil palm plantation in Malaysia in 2014 was 9.97:1 which means that one worker is required for every 9.97 ha of planted area (Ismail *et al.*, 2015). In order to achieve the ideal land to labour ratio, the labour productivity need to increase. Jelani *et al*. (2003) stated that labour productivity can be increased by several factors either by adopting new technology, improving cultural practices, mechanized field operations or improving the quality of the workforce.

Introduction of mechanization to oil palms plantation does help in reducing the number of labour and increase productivity. Despite that, only certain operations have been successfully mechanized such as crop evacuation, herbicide spraying and pesticide spraying. There has been no success in mechanizing the harvesting process. The harvesting process involves identifying ripe bunch by using minimum ripeness standard (MRS), locating the stalk and cutting the bunch stalk. To-date there are no harvesting machine that is as cost effective, efficient and dependable as the human harvester.

Since 1968, study on improving planting materials for ease of harvesting through breeding and selection has been conducted. Longer bunch stalk was suggested as one of the traits that is more directly linked to ease harvesting as it will be easier to hook the sickle between the bunch and the petiole bases (Le Guen *et al.,* 1990). Therefore, commercial planting material with longer bunch stalk length is needed to ensure that harvesting process can be mechanized and labour productivity can be increased.

1.3 Research objectives

This study principally seeks to identify the bunch stalk of more than 25 cm in Deli *dura* × Serdang-AVROS *pisifera* progeny and Serdang-AVROS *pisifera* male parent. The specific of objectives of the study were:

1. To estimate the narrow-sense and broad-sense heritability values of bunch stalk length trait, vegetative traits and yield components.
2. To evaluate general combining ability (GCA) of parents for bunch stalk length trait through progeny testing.
3. To analyse the correlation between bunch stalk length with traits of economic importance.
4. To analyse path coefficient analysis between all the traits studied with oil yield.

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APPENDICES

BIODATA OF STUDENT

Wan Rusydiah binti W Rusik was born in Kajang, Selangor, Malaysia, on the 23rd October 1988. She received her early education at Sekolah Kebangsaan Convent Kajang (1995-2000) and Sekolah Menengah Convent Kajang (2001-2005). She then pursued her study at Kolej Matrikulasi Melaka (2006-2007) for matriculation programme before commencing Bachelor's Degree of Science (Nuclear Science) at Universiti Kebangsaan Malaysia in 2007 (2007-2010).

Immediately after final year exam completion, she joined Sime Darby's Management Apprenticeship Programme (MAP) as a trainee at Oil Palm Breeding Unit, Sime Darby Plantation R&D Centre. After eleven months of training, she was employed as Biotechnologist – Oil Palm Breeding Unit in 2011. She then decided to pursue her study majoring in Genetics and Breeding at Universiti Putra Malaysia in 2016 to gain in-depth knowledge in her field of work.

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