UNIVERSITI PUTRA MALAYSIA

OIL PALM GENETIC ORIGINS, POLLINATOR INSECT AND ENVIRONMENTAL FACTOR EFFECT ON FRUIT SET RATIO AND YIELD COMPONENTS UNDER TROPICAL PEAT SOIL

SWARAY SENESIE

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By

SWARAY SENESIE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

March 2021

DEDICATION

I dedicate this piece of work to Almighty Allah (Subhaanahu WA Ta'aala) and our beloved Prophet Muhammad (Allah's peace and blessing be upon him) as well as his companions and the rest of Muslims Ummah, including my lovely late parents (Pa Alpha Swaray and Mrs. Esther Kadiatu Swaray), and my beloved wife Mrs. Georgiana Felicity Kadija Swaray, and children.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

OIL PALM GENETIC ORIGINS, POLLINATOR INSECT AND ENVIRONMENTAL FACTOR EFFECT ON FRUIT SET RATIO AND YIELD COMPONENTS UNDER TROPICAL PEAT SOIL

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Chairman : Professor Mohd Rafii Yusop, PhD
Faculty : Agriculture

Oil palm industry in Malaysia has been facing a declining trend in fruit set and oil yield. To determine the major factors causing the decline, a comprehensive study was carried out by investigating the performance of parental *dura* (D) and *pisifera* (P) genetic origins on their biparental D×P progenies, pollinator insect and environmental factors. The planting materials used in this study consisted of 24 D×P progenies developed through biparental breeding design. Genetic origins comprised of six female *duras* (Deli Serdang, Tanzania, Angola, Deli Ulu Remis, Deli Johor Labis and Deli Banting) and four male *pisiferas* (Cameroon, Algenene-vereniging rubber planters (AVROS), Nigeria and Yangambi) were hybridized by Malaysian Palm Oil Board (MPOB). The research was conducted at MPOB Research Station, Teluk Intan, Perak. The trial was established in September 2008 in an independent complete randomized design (ICRD) with a triangular planting distance of 8.5 meters on 12.06 hectares with 1930 palms. Data collection on yield and fruit bunch characteristics were carried out as well as inflorescence sex ratio (ISR), fruit set ratio (FSR), *Elaeidobius kamerunicus* (EK) population size and climatic data. Analysis of variance showed that there was greater genetic variability among the D×P progenies. Progeny ECPHP500 produced the highest fresh fruit bunch (FFB, 184.62 kg palm^{-1}yr^{-1}). Progenies PK4674 and PK4465 had the highest FSR at 61.12 and 60.93%, respectively. The highest oil yield (POY) was recorded from progeny PK4674 with 52.66 kg palm^{-1}yr^{-1}. By using an unweighted pair-group procedure with arithmetic mean (UPGMA) and principal components analysis (PCA), the 24 progenies were grouped into seven different clusters. For fruit bunch quality traits, including FSR and POY found that progeny PK4674 was the most outstanding among other progenies. The 'S-shape" technique in determining fruit set showed that PK4674 had the highest FSR (65.78%). Analysis of variance also exhibited that ISR influenced the decline in FSR among the progenies and their parental lines. PK4841 recorded with highest male flower production at 5.85 palm^{-1} year^{-1}. The analysis of variance also showed the occurrence of variability in EK populations and efficiency among the progenies. Also, the present study indicated a decline in EK population force and efficiency, only three progenies (PK4674, PK4465 and PK4482) were above 60% critical level of FSR. Among the genetic origins, Deli

Banting × AVROS recorded the highest population force of EK, but Deli Ulu Remis × AVROS had the highest fruit to bunch (FTB) and FSR. Regression analysis indicated that the relationships of EK population with average bunch weight (ABW), fertile fruit (FF), FTB, ISR and FSR were found to be moderate, where the EK accounted for 25% of the variation in ABW, 37% in FF, 31% in FTB, 26% in ISR and 33% in FSR. The regression results showed that oil to bunch (OTB) was observed to be the highest contributor to POY followed by mesocarp to fruit (MTF) and FFB. Low EK population especially male weevils were observed to be the major factor in FSR decline, followed by wind velocity and field temperature. The findings from this study recommended that Deli Ulu Remis × AVROS, and progeny PK4674 were selected for production of the superior D×P planting materials with high fruit set ratio and oil yield traits.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

ASAL USUL GENETIK KELAPA SAWIT, SERANGGA PENDEBUNGAAN DAN FAKTOR ALAM SEKITAR TERHADAP NISBAH PEMBENTUKAN BUAH DAN KOMPONEN HASIL SAWIT DI TANAH GAMBUT TROPIKA

Oleh

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Industri kelapa sawit di Malaysia menghadapi trend penurunan buah dan hasil minyak. Untuk menentukan faktor utama penyebab penurunan, kajian komprehensif perlu dilakukan dengan menyiasat prestasi asal usul genetik induk *dura* (D) dan *pisifera* (P) pada keturunan D×P dwi-induk mereka, serangga pendebungaan [*Elaeidobius kamerunicus* (EK)], dan faktor-faktor persekitaran. Bahan tanaman yang digunakan dalam kajian ini terdiri daripada 24 progeni D×P yang dihasilkan melalui kacukan dwiinduk. Asal genetik terdiri daripada enam induk betina *dura* (Deli Serdang, Tanzania, Angola, Deli Ulu Remis, Deli Johor Labis dan Deli Banting) dan empat induk jantan *pisifera* (Cameroon, Algenene-vereniging rubber planters (AVROS), Nigeria dan Yangambi) yang telah dihasilkan oleh Malaysia Lembaga Minyak Sawit (MPOB). Penyelidikan ini telah dijalankan di Stesen Penyelidkan MPOB Teluk Intan, Perak. Percubaan ini ditanam pada bulan September 2008 menggunakan reka bentuk rawak lengkap bebas (ICRD) dengan jarak penanaman segitiga 8.5 meter dengan keluasan 12.06 hektar mengandungi 1930 pokok. Pengumpulan data hasil dan ciri-ciri tandan buah telah dijalankan serta nisbah seks infloresens (ISR), nisbah pembentukan buah (FSR), saiz populasi *Elaeidobius kamerunicus* (EK) dan data iklim. Analisis varians menunjukkan bahawa terdapat kepelbagaian genetik yang tinggi di kalangan progeni D×P tersebut. Progeni ECPHP500 telah menghasilkan berat tandan segar (FFB, 184.62 kg pokok^{-1} tahun^{-1}). Progeni PK4674 dan PK4465 memberikan FSR tertinggi masing-masing pada 61.12 dan 60.93%. Hasil minyak tertinggi (POY) dicatat dari progeni PK4674 pada 52.66 kg pokok^{-1} tahun^{-1}. Dengan menggunakan prosedur *unweighted pair-group procedure with arithmetic mean* (UPGMA) dan analisis komponen utama (PCA), 24 progeni tersebut telah dikumpulkan dalam tujuh kluster berlainan. Untuk ciri-ciri kualiti tandan buah, termasuk FSR dan POY didapati progeni PK4674 adalah yang paling cemerlang berbanding progeni yang lain. Teknik *'S-shaped'* bagi menentukan pembentukan buah menunjukkan bahawa progeni PK4674 merekodkan FSR tertinggi (65.78%). Analisis varians menunjukkan bahawa ISR mempengaruhi kemerosotan dalam FSR di kalangan progeni dan titisan induk terlibat. PK4841 telah merekodkan pengeluaran bunga jantan tertinggi iaitu 5.85 infloresens pokok^{-1} tahun^{-1}. Analisis varians juga menunjukkan berlakunya kepelbagaian dalam populasi dan kecekapan EK dikalangan progeni tersebut. Selanjutnya, kajian ini menunjukkan bahawa berlaku penurunan kekuatan dan kecekapan populasi EK, di mana daripada 24 progeni, hanya 3 progeni (PK4674, PK4465 dan PK4482) melebihi 60% paras kritikal FSR. Di kalangan asal usul genetik, Deli Banting × AVROS mencatatkan kekuatan populasi EK tertinggi, manakala Deli Ulu Remis × AVROS pula mempunyai buah ke tandan (FTB) dan FSR tertinggi. Analisis regresi menunjukkan hubungan populasi EK dengan FTB, purata berat tandan (ABW), nisbah buah subur (FF), FTB, ISR dan FSR didapati pada tahap sederhana, di mana EK menyumbang 25% variasi dalam ABW, 37% FF, 31% dalam FTB, 26% dalam ISR dan 33% dalam FSR. Keputusan regresi menunjukkan bahawa minyak ke tandan (OTB) merupakan penyumbang tertinggi kepada POY diikuti oleh mesokarpa ke buah (MTF) dan FFB. Populasi EK yang rendah terutama kumbang jantan didapati merupakan faktor utama dalam kemerosotan FSR dan dikuti oleh halaju angin dan suhu lapangan. Penemuan dari kajian ini mengesyorkan bahawa asal usul genetik dari Deli Ulu Remis × AVROS, dan progeni PK4674 telah dipilih untuk pengeluaran bahan tanaman unggul D×P dengan mempunyai ciri nisbah pembentukan buah dan hasil minyak yang tinggi.

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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 Doctor of Philosophy.

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LIST OF ABBREVIATIONS

A/RF	Average annual rainfall
A/T	Average yearly temperature
AB	Abortion rate
ANOVA	Analysis of variance
AVROS	Algemene vereniging rubber planters,
Bips	Biparental
BNO	Bunch number
CA	Cluster analysis
CABI	Centre for Agriculture and Bioscience International
CAGR	Compound Annual Growth Rate
CDU	Chemara Deli *dura*
CMA/T	Coldest month average temperature
CPO	Crude palm oil
CPOK	Crude palm kernel oil
D×P	*Dura* by *Pisifera*
DNMRT	Duncan new multiple range test
DOA	Department of Agriculture
DRC	Democratic Republic of Congo
ECP	*Elaeis guineensis* crossing program
EF	environment factors
EK	*Elaeidobius kamerunicus*
ENSO	El Niño–Southern Oscillation
EU	European Union
F	Female inflorescences

FAO	Food and agricultural organization
FB	Fruit bunch
FC	Fruit composition
FELDA	Federal Land Development Authority
FFB	fresh fruit bunch
FS	Fruit set
FSR	Fruit set ratio
GA	Genetic advance
GCV	Genotypic coefficient variation
GDP	Gross domestic product
GLM	General linear model
GMS	Genotypic mean square
H	Hermaphrodite flower
h^2_B	Broad sense heritability
HP	Hulu Paka
ICRD	Independent completely randomized design
INF	Inflorescence
ISOPA	International society of oil palm Agronomist
ITIS	Integrated Taxonomic Information System
LAI	Leaf area index
MAD	Malaysian Agriculture Department
MOPI	Malaysian oil palm industry
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Council
MS	Mean square

MSE	Mean square error
MVA	Multivariate analysis
NIFOR	Nigeria institute for oil palm research
NC	North Carolina
NM/RF	Number of months with rainfall less than 100 mm/month
OECD	Organisation for Economic Co-operation and Development
OER	Oil extraction rate
PCA	principal component analysis
PCV	Phenotypic coefficient variation
PEK	Population abundance of *Elaeidobius kamerunicus*
PF/EK	Population force of *Elaeidobius kamerunicus*
PI	pollinator insect
PK	Porim Kluang
PKO	palm kernel oil
POY	Palm oil yield
PROC	Procedure
PS	Plant Series
REML	Restricted maximum likelihood
RM	Ringgit Malaysia
S/V	Source of variation
ISR	inflorescence sex ratio
Stderr	Standard error
SWR-F	Stepwise regression forward
UPGMA	Unweighted pair group technique via arithmetic mean
UPM	Universiti Putra Malaysia

USA	United States of America
USD	United States duller
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 General introduction

The oil palm, scientifically known as *Elaeis guineensis*, is a palm species of Africa, generally called African oil palm. This species has now been naturalized and cultivated in many tropical regions of the world (Universiti Putra Malaysia (UPM), 2019). An increase in the global population has led to a rise in demand for vegetable oil, urging further study into sustainable vegetable oilseeds. The most appropriate among oilseed crops is oil palm, considered as the utmost efficient worldwide (Maluin et *al*., 2020). Through selection and breeding, the oil yield of commercial plantations reached as much as 8 metric tonnes per hectare per year (8 t ha^{-1} yr^{-1}) (Rajanaidu *et al*., (1997). Past studies revealed that with best commercial estate growing conditions, the present yield of this unique crop is still low, classically around 4-6 t ha^{-1} yr^{-1}, and for small-scale farmers, producing about 3-4 t ha^{-1} yr^{-1} (Murphy, 2014). The yield of palm oil is virtually higher than soybean by about 10 and three times higher than coconut (Byerlee *et al*., 2017). Despite being the highest productive vegetable oil crop, oil palm had a minimum of 5% of land use when compared to other oilseed crops (Parveez, 2017; Malike *et al*., 2019).

In several countries, especially in Indonesia and Malaysia, oil palm has been a major commodity crop (Maluin *et al*., 2020). It has certainly contributed immensely and it is still playing key roles in its growing areas' economy throughout the tropical regions and therefore, the importance of oil palm cannot be overemphasized. Malaysia is the largest world palm oil producer and exporter after Indonesia (Darby, 2014; Kushairi *et al*., 2018) and in 2019, India and China were the highest world importers (Daniel Workman, 2020). Oil palm farming contributes immensely towards poverty alleviation with better agricultural policies that transform the livelihood of its growers or related activities of the crop. Several attempts and initiatives have been made by researchers and governments to improve on oil yield to match the growing demand of an ever-growing world population, such as collection, evaluation, utilization and conservation of genetic resources (Malike *et al*., 2019). Different series of oil palm planting materials which are currently in use were developed aiming at different breeding objectives, all gearing towards oil yield improvement.

Oil palm fruit set is presumed to be influenced by factors such as palm genetic origins, inflorescence sex ratio (ISR), pollinator insect (PI) and environmental factors (EF), which may result to low fresh fruit bunch (FFB) yield coupled with reduction in oil yield. Oil palm FFB yield and oil yield improvement have been claimed to hang on the genetically outstanding and unchanging performance of the cultivated planting materials (Rafii *et al*., 2012). Pollen exhibits vital developmental functions to complete the cycle of fruit production, including fertilization, specification and differentiation, and fast polarized development (Wang *et al.*, 2018). Flowers of both sexes are produced on distinct inflorescences of the same palm within the leaf axils in alternate cycles. As a result, its production entails cross-pollination by PI and the most efficient oil palm pollinator insect is *Elaeidobius kamerunicus* (EK) (Auffray *et al*., 2017). The EK have been identified as the most effective oil palm pollinator (Yue *et al*., 2015). Flowering plants and pollinator insects have common correlations while, pollen and nectar are food rewards for pollinators (Siregar *et al*., 2016). The EK is highly reliant on spikelets produced by male inflorescences which they use to animate, feed and reproduce. Extreme drought or rainfall, including some other environmental stresses, have extreme influences on crop production and palm yield is influenced through severe fluctuations in precipitation distribution or its intensity (Nambiappan *et al*., 2018). The situation also affects the population and activities of pollinators. Although several studies have been carried out on the decline in oil palm fruit sets and oil yield, and there has been no known research carried out on major factors responsible for the reduction in fruit sets and oil yield.

1.2 Problem statement

The oil palm industry is facing many constraints, including a decline in oil palm fruit sets and low oil yields. However, several attempts and initiatives have been made by MPOB and the Malaysia palm oil industry (MPOI) to increase the oil yield. The constant decline in fruit set and low oil yield in oil palm plantations in Malaysia gave me the impetus to carry out this study within the scope of four presumed factors i.e., genetic origins, inflorescence sex ratio, pollinator insect and environmental factors. Fundamentally, they are key yield improving factors especially in oil palm plantations. To determine the dominant factors of declining fruit set and low oil yield, it is necessary to investigate through research. Considering the importance of oil palm in the economy of Malaysia and other oil palm growing countries like Sierra Leone, I therefore, intend to explore the major factor in oil palm fruit set decline in 24 D×P biparental progenies on the deep peat-soil environment.

1.3 Main objective of the study

The main objective of the present study was to determine the major factors that caused the decline of oil palm fruit sets.

1.4 Specific objectives

i. To determine the effect of *dura* and *pisifera* origins on fruit set ratio.
ii. To quantify the relationship between fruit set ratio with inflorescence sex ratio and yield components.
iii. To evaluate *Elaeidobius kamerunicus* population size in relation to fruit set ratio.
iv. To determine the most influencing factors on decline in oil palm fruit set yield performance.

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BIODATA OF STUDENT

Swaray Senesie was born on 4th December 1974 in Bonthe Municipality, Bonthe District, Sierra Leone, West Africa. Having completed his Secondary Education at the Bonthe Secondary School in 1996, he gained admission at the Bonthe Technical Training College, Bonthe, Sierra Leone, to pursue a course leading to the award of the Ordinary Technical Diploma (OTD) and Higher Technical Diploma (HTD) in Agriculture General in 1998 – 2000 and 2003 – 2005, respectively. Upon graduation, he was employed as an Assistant Teacher, Islamic Call Society School, Bonthe, Sierra Leone. In 2005/2006 academic year, he enrolled as a Student at the Njala University, Sierra Leone, West Africa, to pursue a course leading to the award of Bachelor of Science with Honours in Crop Science and completed in 2009. He later gained employment at the Bonthe Municipal Council, Bonthe, as a Human Resource Officer (HRO) from 2010 – 2013. In the 2011/2012 academic year, he also enrolled as a student to pursue a Master's of Science Degree in Crop Science (M. Sc. Crop Science) in the School of Agriculture, Njala University, and graduated in 2013. In late 2013 Mr Swaray gained an employment as a Research officer (RO) III at the Sierra Leone Agricultural Research Institute (SLARI), Kenema Forestry Tree Crop Research Centre (KFTCRC). Due to his hard work and job commitment, he was promoted to the rank of Research officer II in 2016. Mr Swaray was awarded a scholarship from SLARI to pursue a PhD degree. He gained an enrolment as a student to pursue a course leading to the award of Doctor of philosophy (PhD) in Genetics and Breeding at the Universiti Putra Malaysia (UPM) in 2017. After obtaining his PhD degree, he will continue to work and contribute to the development of Research in perennial tree crops at SLARI and the world at large.

LIST OF PUBLICATIONS

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