UNIVERSITI PUTRA MALAYSIA

# A MECHANICAL SYSTEM FOR HARVESTING, IN-FIELD COLLECTING AND IN-FIELD TRANSPORTING OF OIL PALM FRESH FRUIT BUNCHES

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

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**December 2018**

**Chairman : Professor Ir. Desa B. Ahmad, PhD**
**Faculty : Engineering**

Malaysia is the second leading palm oil producing country in the world. The industries are confronted with several challenges that hinder the oil palm extraction rate, such as lack of skilled man-power, and ineffectiveness of the manual harvest and in-field collection and transporting techniques adopted currently for oil palm fresh fruit bunches (FFB). The conventional method, deploys human harvester ranging from an average number of five personnel per team (harvester), working for eight hours a day. Hence, reducing the daily productivity of the industries based on the limited available raw material (FFB), which in turns affects the productivity, and turnover of the oil palm industries. These challenges motivated the design, and fabrication of a machine system, that could harvest, and in-field collect and transport all the cut oil palm FFBs. The first approach, proposed the design, and fabrication of a pneumatic Cantas with a pole length of 3m, air screw driver on 6.3 bar, single stage pump air compressor, that is powered by 3.73 kW gasoline engine. This designed machine operated at 280 $l.min^{-1}$ for cutting of fronds, and FFBs by the attached sickle. The second approach was the design, and fabrication of a flexible Cantas with pole of 3 m, powered by a 0.97 kW gasoline engine, and operated with a six joint pieces of flexible drive shaft (FDS) totalling 6 m long between the engine and the pole. A gearbox that converts rotary motion to operate the cutting sickle was attached alongside with a frond supporting mechanism at the end of the pole, to ease the cutting operation during harvest. A 140 kg lifting capacity hydraulic crane of 7 meters height, with five degrees of freedom, and operated by Power Take OFF (PTO) from the tractor was fabricated to catch the cut FFBs and transport the FFBs to the collecting point. A hexagonal diamond shaped collector-basket was developed at the end of the crane for holding the FFBs in position during harvesting operation. The transitional movement of the mechanical systems was able to harvest five FFBs for 193.48 - 247.00 seconds. It took 641.76 - 666.17 seconds for harvesting, collecting, and in-field transporting of five FFBs to unload at the end of harvesting line. This operation for the total harvesting and transporting FFBs productivity increased by 66.63 - 73.36 % when compared to manual harvesting tool. This concept of harvesting managed to eliminate the loading time of loose fruits when FFB falls to the ground. Thus the average total number of FFBs harvested, collected, and in-field transported were 28.082 to 27.099 FFB.hr$^{-1}$ at both FFB heights of 2-3 and 3-4 meters, compared to 17.383 to 12.723 FFB.hr$^{-1}$ under the manual system. The results from both machine designs, and fabrications introduced a novel automated harvesting and transporting of the FFBs, whereby showing a reduction in the number of required unskilled work force to two personnel (the Cantas operator or harvester, and the tractor driver as the crane operator) as against three currently used. The research achieved in developing an integrated harvesting, collecting, and transporting machine which includes the design and fabrication of the crane harvester, the collector-basket , the modified flexible hose with frond support for modified Cantas and the new pneumatic Cantas. The concept of this integration adopted was to enable the harvesting, collecting, and transporting operations in a single passage, thus eliminating the activities of loading FFBs into the trailer and collecting the loose fruits.

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

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Malaysia adalah pengeluar minyak kelapa sawit yang kedua terbesar di dunia berdasarkan sumbangan nilai ekonomi yang diperoleh daripada produk eksport ini kepada Keluaran Dalam Negara Kasar, dan Lembaga Minyak Sawit Malaysia (MPOB) adalah bertanggungjawab untuk mempromosikan dan membangunkan pengeluaran minyak tersebut. Industri kelapa sawit Malaysia berhadapan dengan beberapa cabaran yang menghalang kadar pengekstrakan minyak kelapa sawit seperti kekurangan tenaga mahir yang mencukupi, dan tidak berkesannya teknik penuaian manual yang digunakan pada masa ini untuk menuai dan mengangkut buah tandan segar kelapa sawit (FFB) yang matang. Kaedah konvensional ini menggunakan ramai pekerja diantara lima pekerja setiap pasukan (penuai) bekerja selama lapan jam sehari. Ini mengurangkan produktiviti harian industri berdasarkan bahan mentah yang diperolehi agak terhad (FFB) dan secara tidak langsung mempengaruhi produktiviti dan perolehan industri kelapa sawit. Cabaran-cabaran ini mendorong untuk merekabentuk dan membangunkan dua mesin automatik yang boleh menuai dan mengangkut semua buah (FFB) kelapa sawit yang dituai. Pendekatan pertama mencadangkan reka bentuk dan fabrikasi cantas pneumatik dengan panjang tiang 3m, pemandu FSru udara pada 6.3 bar, pemampat udara pam peringkat tunggal yang dikuasakan oleh enjin petrol 3.73 kW. Mesin yang direka bentuk ini beroperasi pada 280 l. min$^{-1}$ untuk memotong pelepah dan buah sawit (FFB) oleh sabit yang dipasang. Pendekatan kedua adalah reka bentuk, dan fabrikasi Cantas fleksibel dengan galah berukuran 3 m, dipacu oleh enjin petrol 0.97 kW, dan dikendalikan dengan enam keping aci penyambung pemacu fleksibel (FDS) dengan jumlah ukuran 6 m panjang antara enjin dan galah. Kotak gear yang menukar putaran untuk mengendalikan sabit memotong dipasang bersama dengan mekanisme penyokong pelepah di hujung tiang untuk memudahkan operasi pemotongan semasa penuaian. Kren hidraulik berkapasiti 140 kilogram ketinggian 7 meter, dengan lima darjah kebebasan dan dikendalikan oleh Power Take OFF (PTO) dari traktor itu direka untuk mengumpul buah sawit (FFB)

yang dipotong dan mengangkutnya ke kawasan pengumpulan. Bakul pengumpul berbentuk heksagon dibina dan dipasang dihujung kren untuk memegang buah sawit (FFB) dalam kedudukan semasa operasi penuaian. Peralihan-peralihan sistem mekanikal dapat menuai lima tandan basah buah sawit (FFB) dalam tempoh 193.48 - 247.00 saat. Ia mengambil 641.76 - 666.17 saat untuk menuai, mengumpul, dan mengangkut lima tandan basah buah sawit (FFB) untuk memunggah pada akhir penuaian. Operasi ini untuk jumlah penuaian dan pengangkutan meningkatkan produktiviti FFB sebanyak 66.63 - 73.36% jika dibandingkan dengan menggunakan alat penuaian secara manual. Konsep penuaian ini berjaya menghapuskan masa pemuatan buah lerai FFB yang jatuh ke tanah. Justeru jumlah purata FFB yang dituai, dikumpulkan, dan diangkut adalah 28.082 to 27.099 FFB/jam pada ketinggian 2-3 and 3-4 meter, berbanding 17.383 to 12.723 FFB/jam secara manual. Hasil dari kedua-dua reka bentuk mesin dan fabrikasi memperkenalkan penuaian automatik dan pengangkut FFB yang baru yang menghasilkan pengurangan jumlah tenaga kerja kepada dua orang pekerja (pengendali cantas atau penuai, dan pemandu traktor sebagai pengendali kren) berbanding tiga yang sedang digunakan pada masa kini. Penyelidikan ini berjaya membangunkan sesuatu mesin penuaian, pengumpulan, dan pengangkutan bersepadu yang meliputi rekabentuk dan fabrikasi penuai kren, keranjang pengumpul, hos fleksibel yang diubahsuai dengan pisau sokongan untuk cantas dan cantas pneumatik baru. Konsep integrasi ini digunakan untuk membolehkan penuaian, pengumpulan, dan pengangkut operasi dalam satu phasa dan, dengan itu, menghapuskan aktiviti memuat FFB ke dalam treler dan aktiviti pengumpulan buah sawit terlerai.

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

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## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF APPENDICES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| a | acceleration |
| A | area |
| CPO | Crude Palm Oil |
| F | Force |
| FAO | Food and Agricultural Organization |
| Fav | average hand-grip force |
| Fc | cutting force apply |
| FCM | fruit catching mechanism |
| FDS | transmission system using flexible drive shaft |
| FELDA | Federal Land Development Authority |
| FFB | Fresh Fruit Bunch of Oil Palm |
| Fg | grip-hand force |
| Fgk | grip-hand force applied by the sickle knife |
| Fgs | grip-hand force applied by the Frond Supporter s |
| Fmax | maximum force |
| Fp | pulling force applied |
| Ft | total force applied |
| g | gravity |
| H | FFB height |
| HP | Hours Power |
| ICTM | in-field collector-transporter machine |
| k | length of the Frond Supporter from the rotation center |
| kN | kilo newton |
| La | length of the arc |
| m | mass |
| M | Mechanical system |
| MBC | Mobile Bunch Catcher |
| MPOB | Malaysian Palm Oil Board |
| N | newton |
| OPF | Oil Palm Frond |
| P | Power |

| | |
|---|---|
| p | pressure |
| Q | flow rate amount |
| R | gas constant |
| r | radius |
| RPM | rotary per minute |
| SCF | specific cutting force for oil palm fronds material |
| SIK | sickle knife |
| FS | Frond Supporter s |
| SPDT | single pole double throw center off |
| SPST | single-pole single-throw switch |
| T | absolute temperature |
| V | Volume |
| Vf | force reaction on the front tires |
| Vr | force reaction on the rear tires |
| Ø | clip angle |
| 2T | engine Two Stroke Engine |
| W | force weight |
| Wco | weight for the compressor |
| Wf | weight on the front axle of the tractor |
| Wr | weight on the rear axle of the tractor |
| X | distance between the connecting point for the steel cable and the center of the Frond Supporter rotation. |
| x | Distance between the wheelbase for the front tires and rear tires |
| xf | distance between the center of gravity for the tractor and the wheelbase of front tires with the ground. |
| xr | distance between the center of gravity for the tractor and the wheelbase of rear tires with the ground. |
| α | oblique angle for Frond Supporter s. |
| β | oblique angle sickle knife. |
| ηhm | hydro mechanical efficiency. |
| ηvol | pump's volumetric efficiency. |
| θ | angle of that arc's length measured in degrees. |

## CHAPTER 1

## INTRODUCTION

### 1.1 Background of the study

Agriculture has been defined as science, technology, and activities applied in the plantation for the purpose of soil cultivation to produce agriculture crop, or livestock breeding (Jamil, 2008). The agricultural industry is an important economic sector that increases income for governments and countries (Nur Syazwani et al., 2014). Even though Malaysia is now an industrialized country, the agricultural sector which was once the mainstay of the national economy remains an essential contributor to the country's economic development.

Agricultural mechanization technologies include both engineering and biological inventions and discoveries, such as modifications to machinery, the physical environment, or biological components of an agricultural system.

Vegetable oils affect food consumption and economic growth. The increase in human consumption of vegetable oils due to population growth and the expansion of the economic growth of developing countries is one of the main reasons for the increase in global demand for vegetable oils (Mahat, 2012). One of the most widely cultivated oil crops in Malaysia is oil palm tree (*Elaeis guineensis Jacq*), which does not have branches, but it has many wide and long leaves called fronds on the top of the tree (see Figure 1-1).

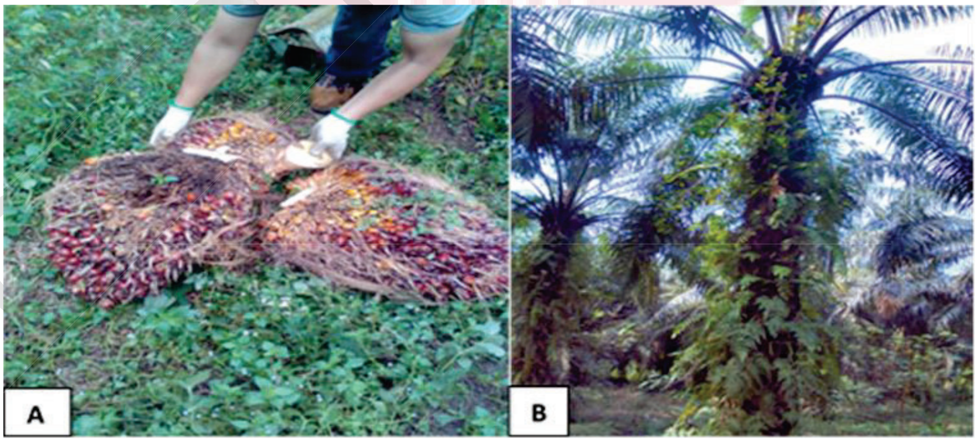


**Figure 1.1 : (A) Oil palm Fresh Fruit Bunch (FFB). (B) Oil palm tree**

The area planted under oil palm worldwide has increased by more than 150 % in the last few decades (Guturu, 2015). The rapid and considerable expansion in oil palm cultivation has resulted in total world production of 101,740,900 tonnes of oil palm fresh fruit bunches (FFBs) in 2017 (FAO, 2018).

Currently, Malaysia is the world's second-largest palm oil producer. Moreover, to maintain and further increase palm oil production capacity, palm fruit harvesting must be sustainable (Yusoff et al., 2014). The total harvested area in 2017 in Malaysia for oil palm fruit was more than 5 million hectares (FAO, 2017). In the last half-century, the Malaysian economy has seen consistently strong growth, rising from USD 8.2 million in 1960 to USD 29.8 million in 2014 (Otieno et al., 2016).

Development in this sector consists of agricultural mechanization which is the primary factor to improve the quantity and quality of agricultural production (Onwude et al., 2016). Agricultural mechanization implies the application of mechanical systems to agricultural engineering principles to minimize the dependence on manual labour and in this way decrease the health and physical risks which workers would expose to as in any industrial or agricultural field (Norzan et al., 2014). Moreover, the development of many countries in Asia and Africa depends on technology that is applied through mechanization in the agricultural sector (Onwude et al., 2016). Enhancing mechanization, specifically of power sources and harvesting equipment, would significantly cut down manual labour requirements and enhance productivity and improve overall worker safety (Sassenrath, 2008).

Leng (1999) report it is without doubt that harvesting, in-field collection, and in-field transportation of fresh fruit bunch (FFB) and fertiliser applications are one of the important keys success of field operations that have the highest impact on field productivity and cost of FFB production. Fruit harvesting and in-field collecting are considered as the most labour-intensive operations to be carried out worldwide, which in many cases represents about 50 percent of total production costs (Jelani et al., 2008). Not only that, it is an arduous task, requiring a lot of body movement such as bending, lifting, stretching, or pushing that must do on the date of harvest within a relatively short period. These combined factors, plus an expensive process have been adversely affected by health, safety, and quality picking issues (Sarig, 2005).

For the last three decades, many harvesting and in-field transporting machines have been developed and innovated by Malaysian universities or government agencies such as the Malaysian Palm Oil Board (MPOB), Federal Land Development Authority (FELDA) and agricultural machine manufacturers in this sector (Norzan et al., 2014). All these machines were attempted to solve problems of low productivity, stressful work and restrictions on the utilization of machinery in peat soils for harvesting and in-field transporting of palm oil fruits on Malaysian plantations.

## 1.2 Agricultural Elements to Produce Fresh Fruit Bunches (FFBs) of Oil Palm

Understanding the principles of the agricultural production cycle will undoubtedly help to improve theoretical concepts and agricultural practices through the establishment of crop production application systems. Some researchers have identified agricultural production practices as essential to human livelihoods or human needs for agricultural products (Kirchmann and Thorvaldsson, 2000; Payraudeau and van der Werf, 2005). Most specialists in agricultural production and environmental protection argue about ways to achieve plantation production outputs employing low agricultural inputs without harming the factors of production (human, animal, plant, soil, water, and atmosphere). There is a need to take advantage of the production tools and agricultural inputs to raise the social level for employees and economic income for both farmers and investors in this sector (El Pebrian and Yahya, 2013; Kirchmann and Thorvaldsson, 2000; Payraudeau and van der Werf, 2005). Agricultural inputs need to include various factors such as land, capital, and labour as well as research, education, communication information, and engineering technology. Such inputs and much more involved agricultural mechanization which must be harnessed (Asoegwu and Asoegwu, 2007; Ismail, 2010).

The farmers and investors in oil palm plantations need a classification for common factors, which are working together and affect each other regarding completing the production process of the fresh fruit bunch (FFB). The three essential joint factors are; manager for the production process (Operator), production environment (Plantation), and the production tools (Equipment). The taxonomy for production process will depend on these factors. Therefore, these factors will be branched to specific categories which represent the required items of the successful production process for FFB. These elements are interrelated to each other (Table 1-1).

**Table 1.1 : Classification of Joint factors for agricultural production processes in general description**

| Joint factors | Main category | Sub-category | References |
|---|---|---|---|
| **Operator** | Owner of the plantation (Farmer) | Farmer or Worker | (Tiffen, 1990) |
| | Investor (Company or Institution) | Worker | |
| **Plantation** | Source of agriculture production | Animals<br>Plants | (Payraudeau and van der Werf, 2005) |
| | Layout | Terraces<br>lines | |
| | Topography | Flat land<br>Hilly area | |
| | Soil | Coherent soils (heavy soils)<br>Peat soils (soft soils) | |
| | Water | Rain<br>Irrigation | |
| | Weather | Light<br>Heat<br>Humidity | |
| **Equipment** | Manual implements | Tillage and land reclamation implements<br>Sowing and crop servicing implements<br>Harvesting and collecting tools<br>Transportation implements | (McNuty andGrace, 2009) |
| | Machines and equipment | Tillage and land reclamation equipment<br>Sowing and crop servicing equipment<br>Harvesting equipment<br>Collecting and transportation equipment | |

Specifically, the argument based on the equipment factor, which represents the adoption of the mechanical harvesting and in-field transporting technologies of the oil palm FFB.

## 1.3 Harvesting and In-field Transporting Activities

Historically, harvesting FFB activity is a task that farmers perform using manual tools (chisel and sickle) which are commonly available in law price (Guturu and Vidhan, 2015). It is clear that manual cutting tools of FFB require skill and effort to achieve an effective cutting (Jelani et al., 2003).

The activities in oil palm plantation that require the machine to perform them are harvesting FFB by cutting the fronds under the bunch, cutting the FFB, collecting and evacuating the FFB, collecting loose fruit, and transport FFB with the loose fruits in the field to the main collecting point (Figure 1-1).

**Figure 1.2 : The main collecting point FFB in plantation area**

Mechanization of the in-field collection and loading activities have been improved at the rate of 83 % in 2008 (Shuib et al., 2011). A large number of innovations have been made in this aspect. From the 1990s to now, the agricultural industry has improved the transport machine including powered wheelbarrow transporter (Hitam and Deraman, 2001), three wheeler machine, prime move for soft ground areas (Awaludin et al., 2015). Also, Rhyno a multipurpose wheel type transporter (Deraman et al., 2013), a special grabber collector (El Pebrian and Yahya, 2013), and mobile bunch catcher (Awaludin et al., 2016). There were machines used for in-field oil palm collection-transportation FFB with engine power 4- 25 HP (El Pebrian and Yahya, 2013). Despite that, the existing machines have to collect the FFBs from the ground and then collect the loose fruits which become detached from the FFBs as they fall to the ground. This takes a long time to complete the task, and need more workers which means more money and less productivity. Therefore to complete the transporting process it is necessary to improve the loading of FFB and collecting of loose fruits. This can be done by integrating all fields' activities which includes the harvesting and transporting activities. Furthermore, integration of these activities in a mechanical system definitely will shorten the time required to complete the production processes and certainly will increase the productivity at a high rate of efficiency.

## 1.4 Statement of the Problems

One of the factors affecting labour ability are weight and vibration. Weight of cutting tool or device usually make the workers suffer from backache problems especially when doing the agricultural task for long time. Attempts need to be made to reduce the number of workers, minimize effort, and increasing the productivity of harvesting machines. Accordingly the barriers faced need to be highlighted and provide suggestions to overcome the problems by considering the criteria (lightweight, full manoeuvrability, high productivity, vast reach range in the vertical and horizontal direction as well as safe and comfortable use) required for the agricultural operations in oil palm plantations. The current in-field collecting and in-field transporting face a problem of sequence processes which means doing the field practices one by one which needs longer time. Similarly in loose fruit collecting and in-field transporting them to the collection centres. The success of harvesting and in-field collecting transporting practices for oil palm FFBs is dependent on skilled workers, but local labourers are not interested in joining the agriculture industry because of the hard work and low pay (Norzan et al., 2014). Nowadays, Malaysia is facing the shortage of skilled and unskilled labourers in the agricultural field (Hitam and Deraman, 2001). The problems facing the harvest and in-field collecting transporting FFBs for oil palm can be summarized as:

1- Harvesting machine (heavy weight).
2- Collecting and transporting FFBs and the loose fruits.
3- Shortage of labours.

Therefore, efforts must make towards increasing the application of science and agricultural technology through the use of modern agricultural mechanization techniques to realize higher agricultural productivity (Wan Ismail, 2010).

## 1.5 Objective of the Study

The primary objective of this project was to evaluate the improved harvesting machine with new in-field collecting and transporting machine for oil palm FFBs, integrated into one mechanical system and to compare it with a manual system. The specific objectives were:

1. To improve the harvesting machines through reducing the weight, and reduce the number of workers involved to two workers.
2. To develop a new in-field collecting transporting machine to improve the collecting transporting FFBs and eliminate the loose fruit issue.
3. To integrate the harvesting, collecting and transporting practices as one mechanical system in a single path at the oil palm trees line.
4. To evaluate the success of the mechanical systems (improved harvesting machines and the new in-field transporting machine) by comparing the time motion study for the field practices and productivity (FFBs per hour) for these practices, with the manual system activities (manual tools).

## 1.6 Scope and Limitation of Study

This research conducted to:

1. Improve the harvesting machine and develop a new frond support mechanism at the head of motorized cutter.
2. Create new design for the In-field transporting machine that can reduce the time required for the collecting process through integration of harvesting and transport activities in a single operation.
3. Integrate the harvesting, in-field collecting, and in-field transporting activities for oil palm FFB, which helps to reduce time (time motion study in seconds for field practices: pruning oil palm fronds, cutting FFB, stake oil palm fronds, collect FFB, and transport FFB to the loading area) required for these activities and productivity (FFBs per hour) for them, as well as number of labours involved.

The improved harvesting machines and the new prototype of the in-field collector transporter machine have limitations which can be summarized as:

1. The mechanical cutter cannot harvest tall trees with FFBs having height of more than 5 meters.
2. The improved motorized cutter cannot be utilized without Kubota tractor because the power source used for the motorized cutter is fixed on the tractor frame.

3. The in-field collecting transporting machine (ICTM) attached with Kubota tractor L2800 D is not suitable for the hilly areas or uneven land, which is difficult to drive the tractor in.
4. The Kubota L2800 D with the new transporting machine ICTM was not able to be used in peat soil unless replaced with wide and flat tires.
5. The in-field collecting transporting machine (ICTM) can unload the FFBs in any direction provided in case that telescopic boom is in the shortest length, otherwise the ICTM with the tractor will collapse, especially to the rear direction.
6. ICTM attached to mini-tractor Kubota L2800 D was supposed to be unloading the FFBs in the basket-collector into the trailer behind the tractor, but the Kubota tractor was not attached with a trailer due to the reason is that the drawbar for the mini-tractor was not able to pull 1000 kg which is the capacity of the normal trailer.
7. The ICTM capacity is five FFBs (20kg for every FFB), four FFBs (30kg for every FFB) or three FFBs (40kg for every FFB), otherwise it will be unstable for the extra FFB and may fall down.

## 1.7 Thesis layout

The thesis is organized to be five chapters in which explain the concepts, design, modification, and work carried out as well as the results taken, conclusion and recommendations that can help in future development. Chapter one presents basic definitions and determines the importance of the palm oil industry and its impact on the agricultural and economic sector, the extent to which the harvest equipment developed and the in-field transport of machinery. In addition, diagnose the problems that still face these machines as well as set goals to solve these problems. Chapter two introduces the equipment and machinery for harvesting and transportation in the field used in palm oil plantations and the extent of development during the last three decades as well as give a glimpse of the idea of work and performance of those machines and equipment. Methodology, design modify, and prototype manufacture explained in Chapter Three. Furthermore, the improvement of motorized cutter used as harvesting machine and the new concept and its improvement, as well as structure of those machines modified, shown in this Chapter. Analysis of results and discussions explained in Chapter Four. Chapter Five contains the conclusions and the recommendations.

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## BIODATA OF STUDENT

Rafea Abdulsattar Mohammed Aljawadi was born in Mosul city, Iraq. He was awarded the B.Sc. and M.Sc. degrees in Agricultural Engineering and Mechanisation by the College of Agriculture and Forests, University of Mosul, Iraq, in 1997 and 2000 respectively. He joined Mosul University as a faculty member in 2001 until now. Presently, he is a Ph.D. candidate at the Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia. During his candidature as a Ph.D. student in UPM, he has published the following papers.

## LIST OF PUBLICATIONS

### Publication

Onwude, Daniel I, Rafia Abdulstter, Chandima Gomesc and Norhashila Hashim (2016) Mechanisation of large-scale agricultural fields in developing countries - a review. *Journal of the Science of Food and Agriculture*, 96(12), 3969–3976. https://doi.org/10.1002/jFSa.7699 (Q1)

Aljawadi, Rafea, A.M., Desa M.N. Nazmi and W.I. Wan Ishak (2018). Development of An Improved Motorised Cutter for Harvesting Oil Palm Fresh Fruit Bunch. *MSAE In Our Food, Our Future* (pp. 205–201).

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### Accepted Paper

Aljawadi, Rafea Abdulsattar Mohammed, Desa Ahmad, Nazmi Mat Nawi, and Muhamad Saufi Mohd Kassim (2018) In-Field Transporting Equipment Currently Used In Oil Palm Plantations in Malaysia: A Review. *International Journal of Engineering Research and Technology.*

### Submitted Paper

Aljawadi, Rafea Abdulsattar Mohammed, Desa Ahmad, Nazmi Mat Nawi, and Muhamad Saufi Mohd Kassim (2018) Mechanized Harvesting of Oil Palm Fresh Fruit Bunches: A review. *Journal of Biosystems Engineering*. (Q2)

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