POTENTIAL OF OIL PALM EMPTY FRUIT BUNCH AND MESOCARP FIBRE AS POSSIBLE COCOPEAT SUBSTITUTE IN FERTIGATION SYSTEM

NURUL LYANA BINTI MAHMOD

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

HORTICULTURE AND LANDSCAPE PROGRAMME FACULTY OF SUSTAINABLE AGRICULTURE UNIVERSITI MALAYSIA SABAH
2015

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: Potential of Oil Palm Empty Fruit Bunch and Mesocarp Fiber As Possible Cocopeat Substitute In Fertigation System.

IJAZAH: Sarjana Muda Sains Pertanian (Kepujian) Hortikultur dan Landskap

SAYA: NURUL LYANA BINTI MAHMOD SESI PENGAJIAN: 2011
(HURUF BESAR)

Mengaku membenarkan tesis *(LPSM/~~Sarjana/Doktor Falsafah~~) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan oleh:
NORAZLYNNE MOHD. JOHAN @ JACKLYNE
PUSTAKAWAN
UNIVERSITI MALAYSIA SABAH

(TANDATANGAN PENULIS)

(TANDATANGAN PUSTAKAWAN)

Alamat Tetap: 10536 JLN BAKTI 6, TAMAN CENDU BAKTI, 78000 ALOR GAJAH, MELAKA.

(NAMA PENYELIA)

TARIKH: ____________

TARIKH: ____________

Catatan:
*Potong yang tidak berkenaan.
*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

NURUL LYANA BINTI MAHMOD

BR11110098

22nd January 2015

VERIFIED BY

1. Puan Rosmah Binti Murdad
   SUPERVISOR

ROSMAH MURDAD
PENSYARAH
FAKULTI PERTANIAN LESTARI UMS

2. Assoc. Prof. Dr. Harpal Singh Saini
   EXAMINER 1

PROF. MADYA DR. HARPAL SINGH SAINI
PENSYARAH
FAKULTI PERTANIAN LESTARI
UMS KAMPUS SANDAKAN

3. Assoc. Prof. Hj. Mohd. Dandan @ Ame Hj. Alidin
   EXAMINER 2

PROF. MADYA HJ. MOHD. DANDAN @
AME HJ. ALIDIN
FELO KANAN
FAKULTI PERTANIAN LESTARI
UMS KAMPUS SANDAKAN

4. Prof. Dr. Wan Mohamad Bin Wan Othman
   DEAN OF FSA

ACKNOWLEDGEMENT

I would like to take this opportunity to say Alhamdulillah towards Allah SWT for to be able to complete this dissertation at the stipulated time. A special thank to the Dean of FSA, Prof. Dr. Wan Mohamad Bin Wan Othman for the help, support and encouragement, I was able to conduct and complete this dissertation successfully. I would also like to thank my parents, Mahmod b. Endut and Fauziah bt. Hasim for their advice and support throughout this dissertation progress. In addition, I would like to thank my supervisor Puan Rosmah binti Murdad for helping, providing tutoring and guidance in completing this dissertation. Your coaches I will not forget until the end of life. Last but not least, my peers who helped me a lot in completing this dissertation. Thank you very much.

POTENSI TANDAN BUAH KELAPA SAWIT KOSONG DAN SERAT MESOKARPA SEBAGAI PENGGANTI SABUT KELAPA DALAM SISTEM FERTIGASI

ABSTRAK

Kajian ini telah dijalankan untuk mengenalpasti potensi tandan buah kelapa sawit kosong dan serat mesokarpa sebagai pengganti sabut kelapa dalam sistem fertigasi. Cili atau nama saintifiknya *Capsicum annuum* telah digunakan sebagai tanaman di dalam kajian ini. Kajian dijalankan di rumah lindungan hujan selama 13 minggu di Makmal Ladang FPL, Kampus Sandakan Universiti Malaysia Sabah. Tujuh jenis rawatan telah diaplikasikan dalam kajian ini iaitu cocopeat (kawalan), tandan buah kelapa sawit kosong dan serat mesokarpa yang diberi rawatan dan tidak diberi rawatan. Benih cili disemai di dalam bekas semaian selama empat minggu sebelum dipindahkan ke dalam polibeg. Parameter yang digunakan untuk mengukur perbezaan antara rawatan ialah dari segi ciri-ciri fizikal (ketumpatan pukal, keupayaan pegangan air), sifat-sifat kimia (pH, EC, N, P, K), sifat-sifat biologi (kandungan bahan organik dan kadar penguraian) dan hasil tanaman (bilangan, berat basah dan panjang buah). Ketujuh-tujuh jenis rawatan yang digunakan telah menunjukkan tindak balas yang berbeza ke atas parameter-parameter yang berkaitan. Penggunaan cocopeat telah menunjukkan hasil yang paling baik dari segi ciri-ciri fizikal, kimia, biologikal dan hasil tanaman berbanding rawatan yang lain. Ciri-ciri fizikal, kimia dan biologikal yang berpotensi digunakan sebagai media penanaman telah ditunjukkan oleh cocopeat diikuti tandan buah kelapa sawit kosong dan serat mesokarpa.

POTENTIAL OF OIL PALM EMPTY FRUIT BUNCH AND MESOCARP FIBRE AS POSSIBLE COCOPEAT SUBSTITUTE IN FERTIGATION SYSTEM

ABSTRACT

This research was done to determine the potential of oil palm empty fruit bunch and mesocarp fibre as possible cocopeat substitute in fertigation system. Chili or *Capsicum annuum* was used in this study. The experiment was conducted under rain shelter building for 13 weeks at the FPL Field Laboratory, University Malaysia Sabah Sandakan Campus. Seven types of treatments were applied in this study such as cocopeat (control), treated and untreated oil palm empty fruit bunch and mesocarp fibre. Chili seeds were sown in nursery tray for four weeks before being transplanted in polybags. The parameters used to measure the difference between the treatments is in terms of physical characteristics (bulk density, water retention), chemical properties (pH, EC, N, P, K), biological properties (organic matter content and rates of decomposition) and yield (number, weight and length of the fruit). Seven types of treatment used showed different responses to the relevant parameters. Cocopeat has shown the best results in terms of physical, chemical, biological properties and yield compared to other treatments. Physical, chemical and biological properties that could potentially be used as a medium for cultivation has been shown by cocopeat followed by oil palm empty fruit bunches and mesocarp fiber.

TABLE OF CONTENTS

Content	Page

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

DM	Dry matter
DMRT	Duncan Multiple Range Test
DMY	Dry Matter Yield
EFB	Empty Fruit Bunch
OPMF	Oil Palm Mesocarp Fiber
MARDI	Malaysia Agriculture Research And Development
POIC	Palm Oil International Conference
MPOB	Malaysian Palm Oil Board
Conc.	Concentrated
PH	Level Of Acidity
EC	Electrical Conductivity
CEC	Cation Exchange Capacity

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

World palm oil production in 1990 doubled to 11.0 million tonnes from 5.0 million tonnes in 1980, and by the year 2000, the production doubled to 21.8 million tonnes. Malaysia produced about half of the world palm oil production (10.8 million tonnes), thus, making Malaysia as world's largest producer and exporter of palm oil during this period (Basiron, 2002). Being the number one trader and the second largest palm oil producer in the world, Malaysia has an important role to play in fulfilling the growing global need for oils and fats sustainably. With a humid tropical climate and temperature ranging from 24°C to 32°C throughout the year, coupled with ample sunshine and an evenly distributed annual rainfall of around 2000 mm, Malaysia is now home to the West African palm first introduced to Malaysia (then known as Malaya) as an ornamental plant in 1875.

In 2013, palm oil and palm oil products contributed RM63.2 billion (8.8%) to the country's merchandise export earnings (Malaysian Digest, 2014). In 2013, the total land area under oil palm plantation in Malaysia is about 5.23 million hectares (MPOB, 2014), which accounts for almost 50% of the total land under cultivation in Malaysia. In spite of the huge production, the oil consists of only about 10% of the total biomass produced in the plantation. The remainder consists of huge amount of oil palm wastes such as oil palm shells, mesocarp fibers and empty fruit bunch (from the mills) and oil palm fronds and oil palm trunk (from the field during replanting). Annually, 90 million tonnes of renewable biomass are in the form of trunks, fronds, shells, palm press fiber, and empty fruit bunch (EFB) are accumulated, where the EFB represents about 9% (Bari *et al.*, 2010).

Table 1.1 Oil palm planted area in Sabah and Sarawak as at December 2013 (hectares)

State	Mature	%	Immature	%	Total	%
Sabah	1,330,039	90.17	145,069	9.83	1,475,108	28.21
Sarawak	961,857	82.85	199,041	17.15	1,160,898	22.20
Sabah & Sarawak	2,291,896	86.95	344,110	50.40	2,636,006	13.05
Malaysia	4,526,089	86.55	703,650	13.45	5,229,739	100.00

Source: MPOB, (2014)

According to the Malaysian Palm Oil Board (MPOB), until the end of 2013, Sabah had the largest area under oil palm cultivation than any state, at 1.48 million hectares out of the national total of 5.23 million hectares. Eastern Sabah has been identified as being an extremely good location for oil palm, particularly in Tawau, Lahad Datu and Sandakan. Until 2009, there are about 126 mills in Sabah produce close to 5 million tonnes of palm oil and palm oil kernel, mostly which is exported (POIC Sabah, 2014).

Agricultural systems seek to maximize the yield and quality of crops and minimize the costs of production, while maintaining sustainability. A number of studies of different soilless substrates have been made using compost from different sources especially on empty fruit bunch (EFB) and oil palm mesocarp fiber (OPMF). Many of the problems that have been identified have been related to salt problems, structural problems and water capacity problems, all factors that are very critical in an efficient production (Weinhold, 1997). Application of EFB and OPMF as soilless substrate can be considered advantageous as they are abundantly available at the plantation area and reduce the amount of waste materials from the industry.

An emphasis on obtaining high quality uniform soil-less substrates is essential to enhance the organic production, but this needs to be closely co-ordinated with water and fertilization techniques, since the organic fertilizers are releasing their nutrients over a longer period, compared to the immediate availability of chemical fertilizers. There are several characteristics of an ideal growth media that can be divided into physical, chemical and biological properties.

In the field of agriculture, growth medium played an important role in producing good crops. A growth medium can be defined as a substance through which roots grow and extract water and nutrients. The principal difference in growing conditions between plants grown in other media and those raised in soil is the amount of space available for root development. In many cases the development of roots is restricted by container, pot or holding medium in which plants are raised.

In this research, nutrient content in empty fruit bunch (EFB) and oil palm mesocarp fiber (OPMF) were analysed and compared. They were used as growing medium and their effect on growth, dry matter production, nutrient uptake for *Capsicum annuum*, and selected soil chemical, physical and biological properties were evaluated. Most capsicums and chillies are grown in soil, using fertigation system and polyethene mulch. Production of capsicums in fertigation system is very small, but may increase as fruit is of good quality, especially for being clean and even. However, most of capsicums are grown using cocopeat as the growth medium, which causes increases in cost production.

1.2 Statement of the Problem

Generally, objectives of this study are:

1. To determine the differences in physical, chemical and biological properties between treated and untreated oil palm empty fruit bunch and mesocarp fiber as fertigation system medium in one cycle of *Capsicum annuum* production.
2. To determine the effectiveness of treated and untreated oil palm empty fruit bunch and mesocarp fiber as fertigation system medium on the growth and yield of *Capsicum annuum*.

1.3 Hypotheses

H_a: There were significant differences among the treatments in terms of:

a. physical properties of oil palm empty fruit bunch (OPEFB) and mesocarp fiber.
b. chemical properties of oil palm empty fruit bunch (OPEFB) and mesocarp fiber.
c. biological properties oil palm empty fruit bunch (OPEFB) and mesocarp fiber.

H_o : There were no significant differences among the treatments in terms of:

a. physical properties of oil palm empty fruit bunch (OPEFB) and mesocarp fiber.
b. chemical properties of oil palm empty fruit bunch (OPEFB) and mesocarp fiber.
c. biological properties oil palm empty fruit bunch (OPEFB) and mesocarp fiber.

1.4 Significance of the Study

Agricultural waste products, such as empty fruit bunch can be obtained abundantly in our country as Malaysia is a second largest palm oil producer in the world. In Sabah, large quantities of palm waste called Empty Fruit Bunches (EFB) and mesocarp fiber are available from plantations where palm oil is produced. The industrial potentials of oil palm empty fruit bunch and mesocarp fiber have not been reported to our knowledge. The fruit bunches and mesocarp fiber which are by products of oil palm processing are presently industrial wastes. The oil palm empty fruit bunch can be found littered everywhere in palm oil producing areas of Malaysia since the waste have presently no industrial application. The same goes to the mesocarp fiber after the oil is being extracted. Soilless media such as cocopeat is costly to be used as growth medium and many farmers cannot afford them for their crops. The introduction of oil palm empty fruit bunch and mesocarp fiber in the plant can be substituted from cocopeat, rockwool, or vermiculite. It is found as ideal growth media and give the required nutrients needed by the plants.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Introduction To Oil Palm Tree

The oil palm (*Elaeis guineensis*) is a tropical tree known as the African oil palm found in western and central Africa, is one of two species of oil palms in the Arecaceae or palm family. Oil palm was introduced to Malaysia from Nigeria by the British colonialists in 1917 and has fast become a major contributor to the nations GDP with around RM 7 million per annum. Latest figures indicate that over 89 million tonnes of fresh fruit bunch (FFB) is produced per year in Malaysia (Singh *et al.*, 2010).

Oil palm tree will start bearing fruits after 30 months of field planting and will continue to be productive for the next 20 to 30 years; thus ensuring a consistent supply of oils. For efficient productivity, average planting cycle of a palm tree is about 25 years. The oil palm plantations in Malaysia are planted with a density of 148 palm tree per hectare. One stand of oil palm tree occupies 0.0068 ha of land. The oil palm fruit produces two distinct oils which are palm oil and palm kernel oil. Palm oil is obtained from the mesocarp while palm kernel oil is obtained from the seed or kernel. Palm oil is used mainly for the production of margarine and compounds in cooking fats and oils and also for the production of candles, detergents, soap and cosmetic products. Production of palm kernel oil is about 12% of the production of its palm oil. The success of the Malaysian palm oil industry is the result of the ideal climatic conditions, efficient milling and refining technologies and facilities, research and development, and efficient and adequate management skills. Practically all palm oil mills generate their own heat and power through the co-generation system (Noor, 1999).

Malaysian government is fully committed to the expansion of the industry and encourages global expansion of palm oil production. Palm oil is now readily accepted globally and Malaysia has exported palm oil to more than 140 countries in the world.

2.2 Oil Palm Residual Waste

The production of palm oil generates biomass residue from plantation and mill sites. This biomass residue can be classified into six types which are oil palm fronds (OPF) and oil palm trunks (OPT) produced at plantation site, empty fruit bunches (EFB), palm kernel shells, mesocarp fibre and palm oil mill effluent (POME) produced at mill sites. Since the large amount of biomass residue is generated yearly, Malaysia has the potential to utilize the biomass residue efficiently and effectively to other valued products. Thus, this ensures that the oil palm biomass residue can be obtained sustainably (Shuit *et al.*, 2009).

The process of CPO and palm kernels production in palm oil mill generates huge quantity of biomass residue such as EFB, fibre, shell and POME as shown in Table 2.2 and Table 2.3

Table 2.2 Typical product stream distribution in oil palm mills (Yusof, 2006)

	Wet FFB basis		Dry FFB basis	
	(tonnes per hectare)	% FFB	(tonnes per hectare)	% FFB
FFB	20.08	100	10.6	100
Palm oil	4.42	22.0	4.42	41.7
Palm kernel	1.20	6.0	1.20	11.4
EFB	4.42	22.0	1.55	14.6
POME	13.45	67.0	0.67	6.3
Shell	1.10	5.5	1.10	10.4
Fibre	2.71	13.5	1.63	15.4
Total	27.3	136.0	10.6	99.8

Table 2.3 Wastes from palm oil production (Goh *et al.*, 2010)

Wastes	Quantity (ktonnes)
Empty fruit bunches (EFB)	18,022
Palm pressed fibres(PPF)	11,059
Oil palm trunks (OPT)	10,827
Shell	4,506
Fronds	46,837

2.3 Oil Palm Empty Fruit Bunch

Currently, there are more than five million hectares of oil palm plantations in Malaysia (MPOB, 2014). EFB are easily available in Malaysia and the price can reach until RM400 per ton. EFB contains neither chemical nor mineral additives, and depending on proper handling operations at the mill, it is free from foreign elements such as gravel, nails, wood residues, waste etc. However, it is saturated with water due to the biological growth combined with the steam sterilization at the mill. Since the moisture content in EFB is around 67%, pre-processing is necessary before EFB can be considered as a good fuel (Zafar, 2014)

2.3.1 Quantity of Empty Fruit Bunches (EFB)

EFB is one of the major waste products that results after processing of fresh fruit bunches (FFB) in oil palm mills (Lim and Zaharah, 2000). During stripping of 88 tonnes of Fresh Fruit Bunches, about 22 tonnes will end up as empty fruit bunches by-product, which either partially dewatered and used as a fuel in the boilers or recycled back to the field as mulch for oil palms. According to Tanaka *et al.* (2004), EFB is regularly collected and discharged at palm oil mills and left after removal of the fruits. EFB consist of cellulose plus hemicelluloses - 70%; lignin - 17%; ash - 1%. It is partially utilized for mulching and for raw material of fertilizers. But still most part of them are not properly utilized. EFB used to be burnt at the mills, but now the burning is almost banned. Many of them are returned to plantation sites as composts.

Table 2.4 Nutrients content in EFB from various sources

Item	Sources	Nutrient content (%) on dry weight			
		N	P	K	Mg
EFB	Corley, 1971	0.35	0.03	2.29	0.18
	Chan, 1980	0.34	0.03	2.21	0.17
	Gurmit, 1982	0.80	0.10	2.40	0.20
	Ebor, 1985	0.66	0.06	1.20	0.20
	Mean	0.54	0.06	2.03	0.19

The empty fruit bunch (EFB) is a good source of organic matter and plant nutrients. From the above table, the EFB constitutes a large number of K followed by N, Mg and P.

2.3.2 The Use Of EFB As Fertiliser Supplement

Many research findings have shown that oil palm by-product of empty fruit bunch (EFB) is good source of plant nutrients. Their applications to land as fertiliser supplement for crops especially oil palm was found to be beneficial to palm performance and soil physical and chemical properties.

2.3.3 Empty Fruit Bunch (EFB) As Mulching for Oil Palm

The application of empty fruit bunch (EFB) as an organic mulch in oil palm has been receiving increasing attention in recent years. Mulching is the application of materials on the surface to reduce soil temperature and conserve soil moisture to improve growth and yield of plants besides supplying varying amount of nutrients as they decompose.

It has been calculated that EFB mulching at about 27 tonnes per ha is equivalent to present manuring practices with inorganic fertilizers, with some adjustment for unbalance (Loong *et al.*, 1987). Due to the high nutrient content in EFB, it is now utilised as mulch and as a nutrient source in the field. Another advantage of using EFB as mulch is its non - polluting nature. Application of EFB in the oil palm fields is done in various methods. They are placed in a circle around the base of the young palm. For matured palms, EFBs are placed in a heap on the ground in between 2 palms. It is also placed in the palm row or in the middle of 4 palms in alternate interrows of palms. Although, EFBs have been used for mulch, research work was mainly concerned with oil palm yield response to EFB application in the field trials.

In the past, EFB was incinerated in the mill as a means to eliminate this waste as well as to provide energy for the boilers in FFB sterilization. The bunch ash produced, which is about 6.5% by weight of the EFB, contains about 30-40% K_2O. The process of incineration was restricted by the Department of Environment (DOE) through the Environmental Quality Clean Air Regulation Act, 1978. This led to the utilization of EFB to be directly applied to oil palm fields. Long term experiments conducted have indicated that application of EFB to oil palm resulted in very favourable benefits in terms of oil palm growth and yield (Khoo and Chew, 1979; Lim and Chan, 1987).

2.3.4 Benefits of EFB

Empty fruit bunch can also improve soil physical properties by reducing soil compaction and increase the storage capacity of water, especially in dry areas that do not receive adequate amount of rainfall and soil stability. Additionally empty bunches are also excellent for maintaining soil moisture when used as mulch, especially to protect the palm trees that are still small in dry areas. For the younger palm, empty fruit bunches will accelerate growth and good yield. In addition, empty fruit bunches can also control weed growth.

2.3.5 Decomposition of EFB

During EFB decomposition, the concentrations of N, P, Ca and Mg in the EFB tissue increased with time. There were gradual releases of N, P, Ca and Mg from the EFB up to the 317th day (Rabumi, 1998). The study also shows that the first application cycle of EFB had already influenced some of the soil properties. Very little data and information are documented regarding EFB decomposition and nutrient release, and its effects on the soil characteristics.

The decomposition of EFB in oil palm plantations was studied by Hamdan *et al.* (1998). The EFB was spread in the field as a mulch on top of a nylon net, at a rate of 30, 60 and 90 mt/ha/year. At each EFB application rate, spots were selected for nitrogen supplementation to meet a C/N ratio of 15, 30 and 60 (control). Decomposition was estimated by the weight of EFB remaining in the nylon net. The EFB was found to be completely decomposed after 10 months of application. It appeared that the more detailed studies of decomposition of EFB in the field was independent of N supplementation. Carbon and nitrogen are the most important elements in biodegradation process as one or the other is normally a limiting factor (Richard, 2008). C/N ratio is a reliable indicator and used as an index of compost maturity (Inbar *et al.*, 1990).

2.4 Mesocarp Fiber

Mesocarp is a fibrous oily pulp that surrounding the nut and covered by a thin smooth skin (exocarp). Mesocarp fiber also can be referred as palm-pressed fiber. Oil deposition in mesocarp starts at week 15 and continues until fruit maturity at week 20-

21. Almost all the mesocarp oil is deposited between week 19-20 (Razali *et al.,* 2012). The residue remaining after extraction, known as palm-pressed fiber, contains approximately 5–6% residual oil, including high contents of minor components such as carotenoids, tocopherols, tocotrienols, phytosterols, and squalene (Choo *et al.,* 1996).

According to Sreekala *et al.*, (1997) mesocarp fibers are left as a waste material after oil extraction, creating great environmental problems. Malaysia is one of the world major palm oil producing country, as it had processed around 75.5 million tonnes of fresh fruit bunch (FFB) in 2005. From these processed FFB, 11.9 million tonnes of oil palm mesocarp fiber (OPMF) which has constituted about 15.7% of solid biomass of FFB has been generated (Lau *et al.*, 2007). According to Choo *et al.* (1996), oil losses in the fiber after screw press extraction of crude palm oil (CPO) was around 5 to 6% and most of this fiber is normally burned as fuel for boiler in the mills. Besides, the fiber also mixed with kernel shell to use as solid wastes for electricity generation in the mills (Lau *et al.*, 2008). The use of palm oil mesocarp fiber which is readily available at low cost will reduce the rate of waste generated in palm oil mills. It is expected that mill OPMF generation will be in excess trend via limited boiler capacity and increasing demand in FFB processes in the mills. Due to the enormity of the plantation industry, about 10.9 million tons of oil palm mesocarp fiber is being produced annually as agriculture waste and contributes to the accumulation of lignocellulosic waste and cause emission of greenhouse gas to the environment (Shuit *et al,* 2009). Therefore, an alternative disposal method is essential to overcome the abundant amount of OPMF generated in the mills every year.

Yacob *et al.* (2005) also reported that typical oil palm mills waste treatment system in Malaysia is one of the major sources that contributed to the emission of Green House Gas (GHG). For every tonnes of POME being treated, around 12.36 kg of methane gas was estimated to be emitted from open anaerobic ponds (Baharuddin *et al.*, 2009). Bioconversion of these biomasses (OPMF and POME) into valuable product is important to minimize the biomass generation impact to the environment. Traditionally oil palm mesocarp fiber is either used in mulching or incinerated, however both methods are detrimental to the environment thus a more sustainable method is required. Therefore, economic utilization of these fibers will be beneficial to the commercial cultivators and the country as a whole.

REFERENCES

Anonymous. (1998). Functions of potassium in plants. *Better Crops Vol. 82*, 1-5.

Baharuddin, A.S., Wakisaka, W., Shirai, Y., Abd-Aziz, S., Abdul Rahman, N.A. and Hassan, M.A. (2009). Co-composting of empty fruit bunch and partially treated palm oil mill effluent in pilot scale. *International Journal of Agricultural Research.* **4(2)**: 69 - 78

Balick, M.J. and Beck,H.T. (1990). Useful palms of the world. Columbia Univ. Press, New York.

Bari, M. N., Alam, M. Z., Muyibi, S. A., Jamal, P., Mamun, A. A. (2010). Effect of particle size on production of citric acid from oil palm empty fruit bunches as new substrate by wild *Aspergillus niger. J Appl Polym Sci* **10(21)**: 2648-2652

Basiron, Y. (2002). Palm oil and its global supply and demand prospects. Oil Palm Industry Economic Journal, **2(1):** 1–10

Beaton, J., and Espinosa, J. (1996). Fertigation and The Use of Fertiliser. *10th National Agronomy Congress.* pp. 129-134

Brussaard, L., Van Faassen, H.G. (1994). Effects of compaction on soil biota and soil biological processes. In: Soane, B.D., Van Ouwerkerk, C. (Eds.), Soil Compaction in Crop Production. Elsevier, New York, pp. 215–235

Bunt, A.C. (1988). *Media and mixes for Container-Grown Plants. Unwin Hayman, London*

Bunt, A. (1988). *Media and Mixes for Container Grown. 1st Edition.* London: Springer.

Caron, J. N. (1999). Aeration in growing media: recent developments. *Acta Horticulture*, 481: 545-551.

Caron, J. R. (2005). Gas diffusion and air-filled porosity: effect of some oversize fragments in growing media. *Can. J. Soil Sci.*, 85:57-65.

Caron, J., Nkongolo, N.V. (1999). Aeration in growing media: recent developments. Acta Hort., 481: 545-551

Choo, Y. M., Yap, S. C., Ooi, C. K., Ma, A. N., Goh, S. H., and Ong, A. S.H. (1996). *Recovered oil from palm-pressed fiber:* A good source of natural carotenoids, vitamin E and sterols. Journal of the American Oil Chemists Society, **73**:599–602.

Dadey, K.A., Janecek, T., and Klaus, A. (1991). Dry Bulk Density: Its Use and Determination. pp. 551-554.

Decoteau, D.R. (2005). Principles of plant science: Environmental factors and technology in growing plants, Pearson Prentice Hall, Upper Saddle River, NJ.

Doran, J.W., & Parkin, T.B. (1994). Defining and assessing soil quality. In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B.A.(Eds.), Defining Soil Quality for a Sustainable Environment. SSSA Spec. Publ. 35. SSSA and ASA, Madison, WI, pp. 3–21

Ellis, J.R. (1998). Post flood syndrome and vesicular–arbuscular mycorrhizal fungi. J. Prod. Agric. 11, 200–204.

Goh, C. S., Tan, K. T., Lee, K. T., Bhatia, S. (2010). Bio-ethanol from lignocelluloses: status, perspective and challenges in Malaysia. *Bioresour. Technol.* **101**: 4834-4841

Hamdan, A.B., Tarmizi, A.M., and Tayeb, D.M. (1998). *Empty Fruit Bunch Mulching And Nitrogen Fertilizer Amendment*: The Resultant Effect On Oil Palm Performance And Soil Properties. PORIM Bull. Palm Oil Res. Inst. Malaysia

Hoagland, D.R., Arnon, D. I. (1950). The water-culture method for growing plants without substrate. *California Agricultural Experiment Station Circular* **347**: 32

Inbar, Y., Chen, Y., Hadar, Y., Hoitink, H.A.J. (1990). New approaches to compost maturity. *Biocycle* **31(12):** 64-68

Inbar, Y., Hadar, Y., Chen, Y. 1993. Recycling of cattle manure: the composting process and characterization of maturity. *J Environ Qual* **22**: 857-863

Jacobs, D. F. (2009). Growing Media. In D. F. Jacobs, T. D. Landis, & T. Luna, *Nursery manual for native plants: A guide for tribal nurseries - Volume 1: Nursery management. Agriculture Handbook 730.* (pp. 77-93). Washington, DC: Department of Agriculture, Forest Service.

Jacobs, Douglass, F., Landis, Thomas, D., Luna, Tara. 2009. Growing media. Nursery manual for native plants: A guide for tribal nurseries: Nursery management. Agriculture Handbook 730. *Washington, D.C.: U.S. Department of Agriculture, Forest Service.* p. 77-93

Khoo, K. T. and Chew, P. S. 1979. Mulching in an oil palm area with empty bunches. *Selangor Planters' Association Annual Report 1978.*

Kooistra, M.J., and Van Noordwijk, M. (1996). Soil architecture and distribution of organic carbon. In: Carter MR, Stewart BA, eds. Structure and organic carbon storage in agricultural soils. *Advances in Soil Science.* Boca Raton: CRC Lewis Publishers, 15– 57.

Landis, T. D., Tinus, R.W., McDonald, S. E., Barnett, J. P. 1989. Seedling nutrition and irrigation. The Container Tree Nursery Manual. *Washington (DC): USDA Forest Service, Agriculture Handbook 674.* **4:** 119

Lau, H.L.N., Choo, Y.M., Ma, A.N. and Chuah, C.H. 2008. Selective extraction of palm carotene and vitamin E from fresh palm pressed fiber (*Elaeis guineensis)* using supercritical CO_2. *J. Food Eng.,* **84**: 289-296

Lee, M.H., Park, H.S., Yoon, K.J., and Hauser, P.J. 2004. Enhancing the durability of linen-like properties of low temperature mercerized cotton. *Text Resource Journal,* **74**:146-154

Lim, K. C. and Chan, K. W. 1987. Towards optimizing empty fruit bunch application in oil palm. In *Proceedings PORIM International Palm Oil Development Conference 1987.* Kuala Lumpur. p. 235-242.

Lim, K. C. and Zaharah, A. R. 2000. Decomposition and N & K Release By Oil Palm Empty Fruit Bunches Applied Under Mature Palms. Journal of Oil Palm Research **12:** 55-62

Linn, D.M., Doran, J.W., 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. *Soil Sci. Soc. Am. J.* 48, 1267–1272.

Loong, S.G., Mohd, N. and Letchumanan, A. 1987. Optimizing the use of EFB mulching on oil palm on two different soils. Paper presented at the *International Palm Oil Development Conference.* Kuala Lumpur. 15pp.

Magen, H. (1995): Fertigation: An overview of some practical aspects. *Fert. News.* The Fert. Assoc. of India, New Delhi, India.

Malaysian Digest. 2014. Focus On Palm Oil Under 11th Malaysia Plan. www.malaysiandigest.com. Retrieved March 2014.

Massa, D., Incrocci, L., Maggini, R., Bibbiani, C., Carmassi, G., Malorgio, F., Pardossi, A. (2011). Simulation of crop water and mineral relations in greenhouse soilless culture. *Environ. Modell. Softw.* **26**:711-726.

McCall. (1981, January). General Home Garden Series. *Treatment For Control of Soil Organisms*, pp. 1-2.

MPOB. 2014. *Oil Palm Planted Area As At Dec 2013.* bepi.mpob.gov.my. Retrieved March 2014.

Nawawi, M. G. M., Othman, N., Sadikin, A. N. and Ismail, N. C. 2008. Lignocellulostic fibermedia filters as a potential technology for primary industrial wastewater treatment. *Jurnal Teknologi*, vol.49, pp. 149–157

Nielsen, K. L.-K. (1996). *growing media for organic tomato plantlet production.* Retrieved 12 01, 2014, from orgprints.org: http://orgprints.org/1606/1/KTK06009.pdf

Nielsen, K., and Kristensen, K. (2001). Growing Media for Organic Tomato Plantlet Production. pp. 1-8.

Noor, M., Ani, F., and Kannan, K. (1999). Renewable Energy Scenario In Malaysia. *2nd International Seminar on Renewable Energy for Poverty Alleviation.* Dhaka, Bangladesh.

Pan, H.Y., Fisher, K.J. and Nichols, M.A. (1999): Fruit yield and maturity characteristics of processing tomatoes in response to drip irrigation. J. Veget. Crop Prod. **5**: 13-29.

Pardossi, A., Incrocci, L., Incrocci, G., Malorgio, F., Battista, P., Bacci, L., Rapi, B., Marzialetti, P., Hemming, J., Balendonck, J. (2009). Root zone sensors for irrigation management in intensive agriculture. **9**:2809–2835.

Passioura, J.B. (1991). Soil structure and plant growth. Australian Journal of Soil Research **29**, 717–728.

POIC Sabah. 2014. Total production of palm oil and palm oil kernel in sabah. www.poic.com.my. Retrieved March 2014.

Rabumi, W. 1998. *Chemical Composition Of Oil Palm Empty Fruit Bunch And Its Decomposition In Tile Field.* Degree of Master of Agriculture Science Dissertation. Universiti Putra Malaysia.

Raviv, M. W. (2002). substrates and their analysis. *hydroponics production of veg. and ornamental*, 25-101.

Raviv, M., and Lieth, J.H. (2008). *Soilless Culture: Theory and Practice.* Amsterdam: Elsevier.

Rayburn, E.B., Sanderson, M.A., Rotz, A., and Fultz, S.W. 1993. Plant Growth and Development as the basis of forage Management, Agronomy Journal **93**:1282 – 1286. West Virginia University, USA.

Razali, M., Ssomad, A., and Roslan, S. (2012). A Review on Crop Plant Production and Ripeness Forecasting. *International Journal of Agriculture and Crop Sciences.* pp. 54-63.

Richard, T.L. 2008. Cornell composting, municipal solid waste composting. http//www.cals.cornell.edu/dept/compost. Accessed on March 2014.

Saidu, M. S. (2011). Cultivation of oyster mushroom (Pleurotus spp.) onpalm oil emsocarp fiber. *African Journal of Biotechnology Vol. 10(71)*, pp. 15973-15976.

Shuit, S. H., Tan, K. T., Lee, K. T., Kamaruddin, A. H. 2009. Oil palm biomass as a sustainable energy source. *A Malaysian case study.* **34**: 1225-1235.

Silip, J.J. (2014). *Pengenalan kepada Fisiologi dan Teknologi Lepas Tuai Hasilan Tanaman.* Selangor: penerbitan multimedia.

Singh, R. P., Ibrahim, M. H., Esa N. and Iliyana, M. S. 2010. Composting of waste from palm oil mill: a sustainable waste management practice. *Environmental Science and Biotechnology, Springer Science* **14:** 156-167

Singh, R.P., Embrandiri, A., Ibrahim, M.H., and Esa, N. 2010. Management of Biomass residues generated from oil palm mill; vermicomposting a sustainable option. *Resour. Conserv. Recy.*, **55**:423-434

Siviero, P. and Sandei, L. 1999. Fertigation of tomatoes with the mobile bench irrigation system. *Informatore Agrario* **55**: 79-82

Sreekala, M. S., Kumaran, M. G., Thomas, S. 1997. Oil palm fibres: Morphology, chemical composition, surface modification, and mechanical properties. *J. Appl. Pol. Sci.* **66(5):** 821-835.

Sridhar. (2008, June). Sterilization and Disinfection. p. 2.

Stepniewski, W., Glinski, J., Ball, B.C., 1994. Effects of compaction on soil aeration properties. In: Soane, B.D., Van Ouwerkerk, C. (Eds.), Soil Compaction in Crop Production. Elsevier, New York, pp. 167–169

Subbiah, A., and Jeyakumar, S. March 2009. Market Survey of Chillies. Department of Commerce, Sri S.R.N.M. College. 1-3.

Sumathi, S., Chai, S.P. and Mohamed, A.R. 2008. Utilization of oil palm as a source of renewable energy in Malaysia. *Renewable and Sustainable Energy Reviews* **12**: 2404-2420

Tanaka, R., Wan Rosli, W.D., Magara, K., Ikeda, T. and Hosoya, S. 2004. Chlorine-free bleaching of kraft pulp from oil palm empty fruit bunches. *Jpn Agric Res Q 2004* **38**: 275e9.

Treeby, M., Falivene, S., and Skewes, M. (2011). February. PrimeFacts 1089. *Fertigation: Delivering Fertilizer In Irrigation Water*. pp. 1- 4.

Verdonck, O. R. (1983). The physical properties of different horticultural substrates. *Acta Horticulture 150*, 155-160.

Verdonck, O.,D. de Vleeshauwer and R. Penick*, 1983. Cocofibre dust, a new growing mediufor plants in the tropics. Acta Hort., 133:215-220*

Weinhold, F., and Roeber, R.U. (1997). Tolerance of ornamental plants to salt, sodium and chloride in potting substrates containing compost made of separately collected organic residues. *Acta Horticulturae* **450**: 221-228.

Yacob, S., Shirai, Y., Hassan, M.A., Wakisaka M. and Subash, S. 2005. *Baseline Study Of Methane Emission From Open Digesting Tank Of Palm Oil Mill Effluent: Chemosphre*. **59:** 1575-1581.

Yeager, T.H., Fare, D., Lea-Cox, J., Ruter, J., Bilderback, T.E., Gilliam, C.H., Niemiera, A.X., Warren, S.L., Whitwell, T.E., Wright, R.D., Tilt, K.M. (2007). Best management practices: guide for producing container-grown plants. 2nd ed. Southern Nurserymen's Association, Maretta, GA.

Yusof, B. (2002). Palm Oil and Its Global Supply and Demand Prospects. Oil Palm Industry Economic Journal; **2:1**, 1-10

Yusoff, S. 2006. Renewable energy from palm oil: Innovation on effective utilization of waste. *J. Cleaner Prod.* **14(1):** 87–93.

Zafar, S. 2013. Energy potential of empty fruit bunches. www.bioenergyconsult.com. Retrieved March 2014.