BIOFERTILIZERS AS COMPLEMENTARY AMENDMENT TO THE SOLE USE OF CHEMICAL FERTILIZERS IN AN OIL PALM PLANTATION

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FACULTY OF SUSTAINABLE AGRICULTURE
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ABSTRACT

The large tracts of land occupied by oil palm in Malaysia which mainly comprise highly weathered and generally infertile soils require chemical fertilizer use to achieve and sustain high crop yields. The use of biofertilizers is one alternative approach to reduce the use of chemical fertilizers. The primary objectives of this study are to evaluate the effects of biofertilizers on the growth and yield of oil palm, soil chemical and microbial properties and to compare the financial cost benefits between using biofertilizers and conventional fertilizer practices. The study was conducted for three years at Sekong Estate, Genting Plantations in Sandakan, Sabah. A randomized complete block design consisting of 10 treatments with 4 replications each was used in this study. The treatments were three microbial based biofertilizers namely Living Soil Microbes (LSM), Agri-Organica (AO) and Mycogold plus Agricare Bioorganik in various combinations with chemical fertilizers (CF), empty fruit bunches (EFB) and the standard estate fertilizer practice. There were no significant differences in fresh fruit bunch (FFB) yield during the first and second years of the study. However, there were significant differences in FFB yield in the third year. In year 3, the combined application of LSM + EFB + 50% chemical fertilizer resulted in the highest FFB yield (26.17 tons ha^{-1} per year) and the lowest FFB yield was for the zero treatment with a yield of 16.71 tons ha^{-1} per year. The highest oil to bunch ratio (OTB) and mean fruit weight (MFW) resulted from the combined application of LSM + EFB + 50% chemical fertilizer. The combined use of chemical fertilizers, EFB and LSM significantly ($p<0.05$) influenced leaf area in year 3 of treatment with the highest leaf area of 12.79 m^2, 8.21% higher than the standard estate practice. For the soil properties and soil microbial population, there were generally better results for the combined application of LSM +EFB + 50% chemical fertilizer compared to other treatments. The highest total bacteria, actinomycetes and fungi counts were found for both the combined application of LSM + EFB, and the combined application of LSM + EFB + 50% chemical fertilizer. Soil pH at 0-15cm depth increased for all treatments containing biofertilizers but the chemical fertilizer containing treatments decreased the soil pH. The biofertilizer and EFB treatments significantly affected soil total N, available P, exchangeable K and Mg at 0-15 cm soil depth. The application of LSM + EFB + 50% chemical fertilizer resulted in 7.55 % better cost-benefit compared to the conventional fertilizer practice. A combination of LSM, EFB and 50% chemical fertilizer was the best treatment. The millions of hectares of oil palm plantations on mineral soils can consider ways of adopting this approach to fertilization as a form of good and sustainable agriculture practice.

ABSTRAK

PENGGUNAAN BAJABIO SEBAGAI PENAMBAHAN PELENGKAP PENGGUNAAN TUNGGAL BAJA KIMIA DI LADANG KELAPA SAWIT

Kebanyakkan kawasan tanaman sawit di Malaysia merangkumi kawasan tanah yang terluluhawa yang mana secara umumnya adalah kurang subur dan oleh yang demikian, penggunaan baja kimia adalah sangat penting untuk mengekalkan kandungan nutrisi tanah dan hasil tanaman yang tinggi. Penggunaan bajabiologi merupakan salah satu alternatif yang digunakan untuk mengurangkan penggunaan baja kimia. Objektif kajian ini adalah untuk menilai kesan penggunaan bajabiologi terhadap pertumbuhan dan hasil kelapa sawit, kandungan kimia tanah dan juga mikrob tanah, untuk membuat perbandingan kos dalam penggunaan bajabiologi dan amalan pertanian konvensional yang sedia ada. Kajian ini telah dijalankan selama tiga tahun di Sekong Estate, Genting Plantaion di Sandakan, Sabah. Kajian ini dijalankan menggunakan ujikaji rekabentuk rawak lengkap yang terdiri daripada 10 rawatan dengan 4 ulangan. Kajian ini menggunakan tiga jenis bajabiologi yang berasaskan mikrob iaitu Living Soil Microbe (LSM), Agri-Organica (AO) dan Mycogold tambah Agricare Bioorganik dengan beberapa kombinasi dengan penggunaan baja kimia (BK), buah tandan kosong (BTK) dan piawaian amalan baja. Tidak terdapat perbezaan yang ketara terhadap hasil BTS pada tahun pertama dan tahun kedua selepas rawatan. Walau bagaimanapun, terdapat perbezaan yang ketara ke atas hasil BTS selepas rawatan 3 tahun. Penggunaan kombinasi LSM + BTK + 50% baja kimia mencatatkan hasil tertinggi selepas rawatan selama 3 tahun (26.17 tan / ha per tahun) dan hasil BTS yang paling rendah adalah dari plot rawatan sifar iaitu 16.71 tan / ha per tahun. Nisbah kadar perahan minyak (OTB) dan nisbah berat measokarpa (MFW) tertinggi adalah direkodkan daripada kombinasi penggunaan LSM + BTK + 50% baja kimia. Kombinasi penggunaan BK, BTK dan LSM menunjukkan perbezaan yang ketara (p <0.05) terhadap keluasan daun selepas 3 tahun rawatan dengan keluas daun yang tertinggi 12.79 m2, iaitu 8.21% lebih tinggi daripada plot piawaian amalan baja. Secara umumnya, kombinasi penggunaan LSM + BTK + 50% baja kimia menyumbang kepada kesuburan tanah dan populasi mikrob tanah berbanding rawatan-rawatan yang lain. Jumlah populasi bakteria, aktinomiset dan fungi terbanyak ditemui dikawasan plot kombinasi penggunaan LSM + BTK dan kombinasi penggunaan LSM + BTK + 50% baja kimia. Kadar pH tanah pada kedalaman 0-15cm dicatakan meningkat di semua plot yang menggunakan bajabiologi. Walau bagaimanapun, penggunaan baja kimia secara berterusan menurunkan kadar pH tanah. Penggunaan BTK dan bajabiologi memberi kesan yang ketara ke atas jumlah N, P, K dan Mg pada kedalam 0-15cm. Penggunaan LSM, BTK dan pengurangan 50% baja kimia secara teknikal meningkatkan produktiviti tanaman sebanyak 7.55 % lebih tinggi berbanding piawaian amlan baja konvensional. Kombinasi penggunaan BK, BTK dan 50% baja kimia merupakan kombinasi rawatan yang terbaik. Jutaan hektar ladang kelapa sawit di tanah

mineral boleh mengambil kira untuk mengguna pakai pendekatan pembajaan ini sebagai satu bentuk amalan pertanian yang mampan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

%	**-**	Percentage
<	-	Less than
>	-	Bigger than
°C	-	Degree celcius
DM		Dry matter
g	-	Gram
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
mg kg^{-1}	-	Miligram per kilogram
t ha^{-1}	-	Tonne per hectare
ANOVA	-	Analysis of variance
AO	-	Agri organica
EFB	-	Empty fruit bunch
FAO	-	Food and Agriculture Organization
FFB	-	Fresh fruit bunch
FSA	-	Faculty of Sustainable Agriculture
LSM	-	Living Soil Microbes
LAI		Leaf area index
MPOB	-	Malaysian Palm Oil Board
MSPO	-	Malaysian Sustainability Palm Oil
NEP	-	Normal estate practices
RCBD	-	Randomised complete block design
SPSS	-	Statistical Package for Social Science
UMS	-	Universiti Malaysia Sabah

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In Malaysia, oil palm planted area covered about 5.74 million hectares in 2016 compared to 5.64 million hectares in 2015, an increase of about 1.77%. Sabah still has the largest oil palm planted area with 1.55 million hectares, which is 27% of the total oil palm cultivated area in Malaysia. The fresh fruit bunch (FFB) yield for 2014 was lower by 2.1 % at 18.63 tons per hectare from the 19.02 tons per hectare achieved in 2013. Sabah accounted for the highest FFB yield, registering an increase of 2.2% at 21.34 tons per hectare on 2014 and 19.99 tons per hectare on 2013, respectively (MPOB, 2016).

The large tracts of land occupied by oil palm in Malaysia mainly comprise highly weathered soils classified as Oxisols and Ultisols, which are generally infertile (Sanchez and Logan, 1992). These soils need to be amended with chemical fertilizers for maintenance of soil fertility and fulfillment of crop nutrient requirement and sustained crop productivity. Fertilizer is one of the main components of plantation management costs, and thus, efficient and optimum application of fertilizers can contribute to high yields and optimum returns for farmers.

Currently, there is concern about the high use of chemical fertilizers as Malaysian chemical fertilizers consumptions for agriculture use was 1.54 tonnes per hectare made up totaled about 8.69 million metric tonnes in 2015 (Fertilizer Industry

Association of Malaysian, 2015). The application of chemical fertilizers is routine in oil palm plantations to maintain soil fertility. Chemical fertilizer inputs make up about 50-60 percent of the cost for FFB production. However, only about 20-30% of applied chemical fertilizers are actually taken up by the plants. The rest is usually lost through leaching and other means, or are fixed in the soil and unavailable for plant uptake. Some of the leached fertilizers find their way into rivers and streams and other water resources, causing pollution problems such as eutrophication.

Today oil palm plantations constitute the largest sector in the agriculture plantation industry in Malaysia, exceeding rubber plantations by more than double in area planted through the crop diversification program. As such, it is the most important industrial crop and covering about 5.74 million hectares and accounts for about 38.7% of the total world palm oil production (MPOB, 2016). Oil palm remains the golden crop that will continue to significantly contribute to the increase in global oils and fats trade.

Currently, chemical fertilizers play an important role in conventional agriculture to meet food demand. Prolonged and extensive use of inorganic chemical based fertilizers cause air and ground water pollution (Youssef and Eissa, 2014) which poses a serious threat to human health and the environment.

In the Malaysian agriculture sector, other alternatives to reduce the use of chemical fertilizers include replacement by organic based fertilizers to improve nutrient supply and sustainable land management. Organic farming is one alternative adopted to reduce use of chemical fertilizers and to ensure food safety and also increase soil biodiversity (Megali, Glauser and Rasmann 2013).

There are economic, environmental and social implications from the use of chemical fertilizers in agriculture, and more so in oil palm plantations. Oil palm plantations are a primarily soil based and rain fed industrial monocroping system.

Thus, its sustainability and ability to achieve various optima of the cropping system rely on sustaining soil fertility at an adequately high level for crop productivity.

Nowadays, sustainability is a challenging issue face by oil palm industry due to degradation of land, water and ecological impact which lead to formation of Malaysian Sustainable Palm Oil (MSPO). Malaysian Sustainable Palm Oil (MSPO) address sustainability issues and challenges in relation to the multi-stakeholders involve in the industry which complies with Malaysian laws and ratified international agreements.

The standard describes the sustainability requirements for the production throughout the supply chain from the raw materials until the transport to consumer and makes it possible for smallholders to establish, maintain and improve their operational practices within management system framework, which enables the approach towards attaining sustainable production of palm oil (Harnarinder and Sanath, 2016).

Meanwhile, the MSPO would provide a credible sustainable and responsible management, to bring about positive social, environmental and economic impacts, while minimizing the negative impacts, particularly on its people and the environment in oil palm industry. These benefits can be summarized as; improve to standards of management, promotion of sustainable forest management, biodiversity enhancement, social enhancement and improved efficiency leading to economic benefits.

Any alternative technology or approach, either using organic or biofertilizers, that could substitute and/or optimize chemical fertilizer use in oil palm plantations, is worth looking into, as a means of acquiring a more sustainable oil palm industry through ensuring triple wins, for the people, planet and profit which is supporting Malaysian Sustainable Palm Oil (MSPO) mission as mentioned above.

In this respect various biofertilizer microbial based materials are being tried in this research to evaluate whether they could substitute, replace or complement the sole use of chemical fertilizers in oil palm plantations.

1.2 Objectives

i. To evaluate the effects of biofertilizers on the growth and yield of oil palm.

ii. To evaluate the effects of biofertilizers on soil chemical and microbial properties.

iii. To compare the financial cost benefits in using biofertilizers and conventional practices.

CHAPTER 2

LITERATURE REVIEW

2.1 History and Origin of Oil palm

The oil palm (*Elaeis guineensis*) originated from West Africa. The first commercial scale oil palm plantation in Malaysia was established in 1917 at Tennamaran Estate in Selangor. The palm oil industry in Malaysia has evolved dramatically since the first commercial planting took place in Tennamaran Estate in Selangor in 1917, laying the foundations for the industry in Malaysia. The cultivation of oil palm increased in the early 1960s under the government's agricultural diversification programme, which was introduced to reduce the country's economic dependence on rubber and tin (Corley, and Tinker, 2003).

2.2 Agronomic Requirements

There are many factors that influence oil palm growth and production. However, the main factors are climate, soil type and crop management. Suitable climate is essentially for successful oil palm cultivation. Climate parameters such as temperature, light, and rainfall are the main drivers for oil palm growth and production. Besides, soil is a medium for oil palm growth, its supply of nutrients and water. Although the oil palm could grow on a wide range of soils but for healthy growth and optimum yield it needs a suitable type of soil, climate and good management practices (Corley, and Tinker, 2003).

2.2.1 Climate and Weather

The oil palm (*Elaeis guineensis*, family Arecaceae) is a tropical forest palm native to West and Central African forests. Oil palm thrives well in the humid tropics and requires evenly distributed rainfall of 150 mm to 250 mm per month or 2500 mm to 4000 mm per annum. The oil palm grows well at temperatures between 29-33℃ (maximum) and 22-24℃ (minimum) and bright sunlight for at least 5 hours per day. Humidity of more than 80% is required good growth (Corley and Tinker, 2003).

Climate and edaphic factors are known to affect the performance of oil palm. The former, which is considered to be more influential on oil palm performance, includes drought severity, excessive rainfall, wind gust, sunshine duration and diurnal temperature changes (Jalani, 1998). Basiron (2007) reported that, seasonal droughts at higher tropical latitudes greatly reduce yields. Prolonged dry conditions for about 8 to 16 weeks would cause moisture stress in oil palms and reduce yield production by up to 30% depending on the severity, while prolonged heavy rainfall results in poor pollination and can reduce potential yields by 15 %. Mild or moderate monsoons are beneficial to the palm and are usually associated with high palm oil production.

2.2.2 Soil and Nutrient Management

Oil palm is tolerant of a wide range of soil types, as long as it is well watered. The oil palm is cultivated predominantly on tropical soils mainly Ultisols, Oxisols, and Inceptisols and to a lesser extent histosols. These soils are highly acidic with low buffering capacities as a consequence of cations leaching (Ng, 2002).

However, oil palm is adapted to acidic conditions (Mutert, 1999), and with appropriate management, oil palm plantations can also be productive on "problem soils" such as acid sulfate soils, deep peat and high aluminum acidic soils, where few other crops are successful (Corley and Tinker, 2003), through the application of large amounts of commercial fertilizers, which thus makes oil palm plantations the largest consumers of mineral fertilizers in Southeast Asia (Hardter and Fairhurst, 2003).

Many researches have been conducted to highlight the importance of fertilizers for oil palm cultivation. The main reason is that healthy and proper growth of the palms will produce optimum fresh fruit bunch (FFB) yields. However, to produce optimum FFB requires a large amount of nutrients, otherwise insufficient nutrients will reduce FFB yields. Unfortunately, most soils in oil palm plantations are problem soils with low soil fertility. Therefore, application of mineral fertilizers is necessary to sustain optimum FFB yields. Long term application of chemical fertilizers would contribute to soil acidification, which causes low soil pH and reduces the buffering capacity in soils (Comte, Colin, Grünberger, Follain, Whalen, and Caliman, 2013)

The oil palm fertilizer requirements differs from one environment to another and is correlated to many factors such as, the yield responses of oil palm to fertilizers and agro-ecological environments (Foster, 2003). The optimum fertilizer requirements of oil palm can be determined based on principles of plant mineral nutrition requirement and soil fertility (Fairhurst and Mutert, 1999). Table 2.1, 2.2 and 2.3 show the nutrient concentrations for young and mature oil palm and classification of soil nutrients for determination of fertilizer requirements in oil palm plantations.