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Engine Performance Analysis Using Biodiesel from Giant Palm *as* a Blending Agent

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ABSTRACT

The continuous reliance on petroleum diesel, coupled with growing concerns about environmental degradation, has propelled the exploration of renewable diesel fuel alternatives. This research study delved into the production of giant palm seed oil methyl ester through transesterification, employed potassium hydroxide as a catalyst. This alternative fuel was then tested in a single-cylinder, direct injection diesel engine commonly used in Nigeria's agricultural sector, where the demand for sustainable energy solutions is crucial. Pure vegetable oils encounter operational challenges in diesel engines due to their high viscosity, low calorific value, and polyunsaturated nature. Transesterification emerges as a more effective method to modify these properties. Comparisons between the physicochemical parameters of giant palm seed oil methyl ester and conventional diesel fuel revealed significant differences. The calorific value of the produced biodiesel stood at 38.470 MJ/kg, slightly lower than pure diesel's 42.00 MJ/kg. Additionally, the kinematic viscosity of the biodiesel was measured at 10.9 mm^2/s. The study also scrutinized engine performance using various biodiesel blends and compared them with conventional diesel. The findings demonstrated the viability of using biodiesel derived from giant palm seed oil in compression ignition engines as a practical alternative to diesel fuel. Lower blends, particularly B5 to B25, adhered closely to ASTM standards, signifying their acceptability. However, as biodiesel concentration increased, both break thermal efficiency and fuel consumption experienced an upward trend. The results showed that the use of biodiesel produced from giant palm seed oil in compression ignition engines is a viable alternative to diesel fuel.

Keywords: Biodiesel, brake specific fuel consumption, brake thermal efficiency, giant palm seeds, single cylinder engine

INTRODUCTION

Biodiesel is an important sustainable renewable energy source that can potentially replace petroleum-based diesel and fulfill environmental and energy security needs without sacrificing operational performance or conditions. The fuel exhibits properties and performs similarly to that of a conventional diesel in terms of engine performance and eco-friendly emissions without any modifications to existing engines (McCarthy *et al.* 2011). Non-edible oils are more suitable to be used for biodiesel production. This is because they are not competing with food

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materials; moreover, most non-edible oil seeds are grown in the wild and under-utilized, especially in Nigeria. These wild plants do not require any care but simultaneously will provide a good source of income to rural dwellers through the collection of seeds for biodiesel production. More so, the use of biodiesel as a blending agent in diesel fuel has become a global trend, with many countries passing legislation requiring diesel to contain a minimum percentage of biofuels. Biodiesel produced from non-conventional sources such as vegetable oils, fat, palm oil, soybean, coconut, and others offer a viable alternative fuel for diesel engines. These alternative biodiesel fuels are readily available in Nigeria and can be obtained locally in large quantities (Ajie *et al.* 2023). The blending of pure diesel and even low percentages of biodiesel will contribute to the local economy of the nation and reduce poverty levels. However, the performance of biodiesel blends in compression ignition engines is still a subject of research. Several studies have investigated the effect of biodiesel blends on engine performance and emissions. The results have shown that brake-specific fuel consumption and brake thermal efficiency can increase with biodiesel blends but are likely to produce less power with high fuel consumption than diesel due to its lower gross calorific value. Additionally, the high viscosity of biodiesel can cause fuel flow and ignition problems in unmodified compression ignition engines (Ajie *et al.* 2023).

Borassus aethiopum is called different names by the different ethnic groups in Africa and is a popular palm tree in some regions (Waziri *et al.* 2010). It is a typical savanna tree with a density of not less than 20 palms per hectare and is almost absent in other vegetation (Mollet *et al.* 2000). *B. aethiopum* is widely cultivated and used economically in Nigeria and other African countries. The palms are the most numerous trees in the world after coconut (Asante *et al.* 2011). The plant has various uses and contributes significantly to household incomes in the communities where it is found. In areas where the plant exists, harvesting, selling and palm wine taping provides one of the most important annual incomes (Sambo *et al.* 2002).

Almost all the parts of the palm plant are used for various purposes including food, building materials, household items as well as medicinal purposes. The fruits are major source of food, and it is also an income earner for many households through the sale of fans and mats weaved from the leaves. Asante *et al.* (2011) reported that the processing of palm tree products generates food and income for craftsmen and households in villages where the plants are available. The stems can be split into timber and the leaves are used for the construction of houses in local settings. Figure 1 and 2 shown bunches of giant palm fruit on a tree, and giant palm seeds, respectively. Transport sector plays a key role in the socio-economic development of any country. The number of trucks in Nigeria increases tremendously on daily bases, which has further demand for eco-friendly fuels.

As a result, there is a rapid increase in the consumption of fossil fuels and this has contributed to climate change which is considered the most important environmental problem of the present century (Dwivedi *et al.* 2013). According to recent studies, the emission of greenhouse gases has caused an increase in the global mean temperature by approximately 0.8 °C over the past century (Dwivedi *et al.* 2013). This has led to the need for eco-friendly and renewable energy sources such as solar, wind, hydro, and biomass. Renewable energy sources, particularly biomass energy, can reduce Nigeria's dependency on imported petroleum products. Biodiesel, a liquid biofuel, can replace conventional diesel and generate new economic opportunities in rural areas while protecting the environment. In evaluating materials for biodiesel production, it is important to consider their availability, similar properties to conventional diesel, and economic value compared to fossil diesel. Non-edible oils is

Figure 1 Bunches of giant palm fruit on a tree.

Figure 2 A tropical giant palm seeds.

more suitable for biodiesel production as they do not compete with food sources (Lapuerta *et al.* 2008). By utilizing renewable energy sources and biodiesel, we can reduce our carbon footprint and protect the environment while creating new economic opportunities. Most of the seeds of non-edible oils are wasted in the wild. These wild plants do not require any care but simultaneously provide a good source of income for local people through the collection of seeds for oil production (Shojaeefard *et al.* 2013). Giant palm seeds are promising feedstock for biodiesel production and were considered for this research work. Today, oil from giant palm seeds has not been established whether is edible or not, and some researchers have worked on the medicinal part of the seed and fruit. Biodiesel has the following major advantages; it can be blended with diesel fuel at any proportion, can be used in a diesel engine without any modification, does not contain any harmful substances, and produces less harmful emissions to the environment. This research work provides useful information to designers, engineers, industrialists, and researchers who are interested in biodiesel production from vegetable oils. The objective of this study was to determine the suitability of using biodiesel derived from giant palm seed oil and investigate the effect of giant palm biodiesel addition in volume and compared with conventional diesel fuel using a single-cylinder stationary diesel engine.

MATERIALS AND METHODS

Biodiesel Sample Preparation

A wild giant palm seed was collected and dried under ambient temperature, and oil was extracted using a designed roaster expeller. The extracted oil was converted to fuel using an alkaline transesterification process with potassium hydroxide as a catalyst and methanol as a solvent. Two percent catalyst was dissolved in methanol for the experiment, and the mixture was added to the measured giant palm oil. The prepared mixture was then stirred at the required temperature and time. The reactant product was put into a clear container and allowed to settle for nearly 6 hours at room temperature. Glycerin was left on the bottom of the container while methyl ester was on top, and biodiesel was poured into another vessel that had been cleansed and filtered after the mixture had settled. To eliminate liquid remnants, the collected fuel was heated for 10 minutes at 110 °C. After that, the recovered fuel was allowed to cool to ambient temperature. The finished product (biodiesel fuel) was mixed with diesel fuel in the following proportions: 5%, 10%, 15%, 20%, 25%, 50%, and 100%, designated as B5, B10, B15, B20, B25, B50, and B100, respectively. Biodiesel blends were used to test engine performance while the performance indices were used to calculate some of the parameters. Table 1 present fuel properties of giant palm seed oil and giant palm methyl ester (biodiesel) in comparison with mineral diesel.

Experimental Setup for Biodiesel Evaluation

An experimental setup was developed to evaluate an engine's performance using biodiesel from giant palm seed oil. The experiment unit consists of various structural and instrumental panels listed in Table 2. A JUMBO stationary diesel engine, single cylinder, four strokes, vertical and cold starting totally enclosed, water-cooled CI engine was used for experimental investigations. This type of stationary engine is commonly used for farming operations in Nigeria. The engine specifications are shown in Table 3. The engine was coupled to a dynamometer to measure the engine torque. The setup was installed at the Farm Power and Machinery Laboratory, Food and Agricultural Engineering Department, Kwara State University, Malete, Nigeria. Experiments were conducted first with conventional diesel to establish reference parameters and various blends of giant palm biodiesel were used to run the engine for 30 minutes each. The speed of the engine was measured in RPM with a handheld tachometer. The engine fuel tank was disconnected, and the fuel was consumed only from the calibrated burette. An electrical alternator (Table 4) was connected to the engine to vary the engine loads, which contained a load bank. The load bank consists of thirty bulbs of 200 W each, the bulbs were grouped into six with five bulbs in each group, and each group was controlled with a switch. Figure 3 shows the experimental setup used for the performance evaluation of biodiesel blends and load bank.

Table 1 Fuel properties of giant palm seed oil and giant palm biodiesel in comparison with mineral diesel.

Properties	Giant palm seed oil	Giant palm biodiesel	Mineral diesel (Acharya *et al.* 2016)
Density at 20 ºC, (g/cm^3)	960.0	913.6	0.824
Kinematic viscosity (mm^2/s)	23.87	10.90	2.300
Calorific value (kJ/Kg)	35.68	38.47	42.00
Flash point (ºC)	270.0	150.0	53.00
Specific gravity	0.962	0.955	-
Acid value gKOH/g	6.680	4.480	-

Table 2 List of structural and instrumental panels for experimental setup in biodiesel evaluation.

S/N	Items	Requirements
1	Foundation	2, engine and alternator base
2	Lister engine	1
3	Alternator	1
4	Load panel	1
5	Dynamometer	1
6	Tachometer	1
7	Burette (100 mL)	1
8	Giant palm seed oil Biodiesel produced	

Table 3 Engine technical specification panels for experimental setup in biodiesel evaluation.

Item	Technical data
Model	JUMBO stationary diesel engine
Type	Four stroke, vertical and cold starting enclosed
Horsepower	8
Bore (mm) x stroke (mm)	114.3× 139.7
Rotation	Clockwise
Combustion principle	Compression ignition
Cubic capacity (CC)	1432.71
Rated RPM (rpm)	850
Flywheel diameter (mm)	590
Flywheel width (mm)	90
No. of cylinder	One
Method of cooling	Water
Starting	Hand start with a cranking handle
Bearing	Taper roller bearings
Lubrication system	Splash lubrication system

Table 4 Alternator specifications panels for experimental setup in biodiesel evaluation.

S/N	Particular	Specifications
1.	Model	Delmax
2.	Output	7.5 KVA
3.	Volt	230
4.	RPM	1500
5.	Frequency (Hz)	50
6.	Type of cooling	Fan cooled

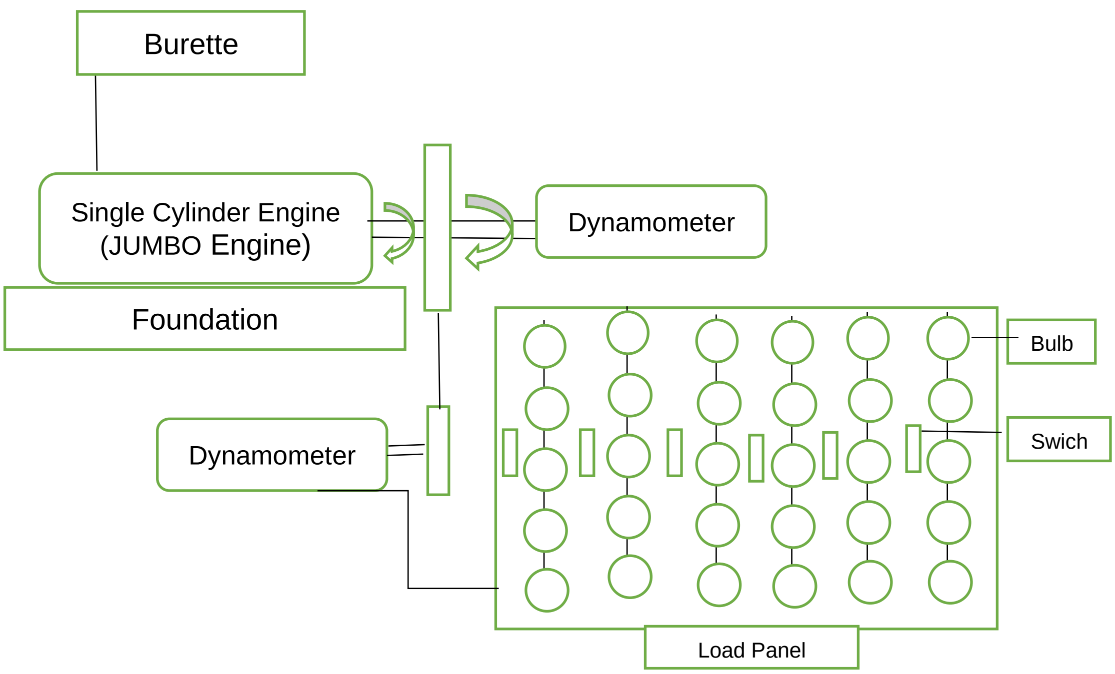

Figure 3 Experimental setup in for biodiesel evaluation.

Experimental Procedure

The engine was first tested using conventional diesel to provide baseline information for the experiment. Thereafter, all measurements were taken after the engine was stabilized. The experiments were repeated with the blends of methyl ester of giant palm seed oil for comparison. The test was conducted in accordance with the standard in the following sequence: pure diesel, B5 (5% biodiesel and 95% diesel), B10 (10% biodiesel and 90% diesel), B15 (15% biodiesel and 85% diesel), B20 (20% biodiesel and 80% diesel), B25 (25% biodiesel and 75% diesel), B50 (50% biodiesel and 50% diesel), B100 (pure biodiesel). The engine fuel consumption was measured using calibrated burette (100 mL). The burette was filled with fuel well above the top marking while the stopcock was locked, after that the stopcock was on to allow the passage of fuel into the engine. The engine was operated for 30 minutes in each case and the fuel consumption was recorded.

RESULTS AND DISCUSSION

Brake Specific Fuel Consumption (BSFC)

Figure 4 shows the findings for the variation in the BSFC as the engine's biodiesel content increases up to the maximum load. Due to its higher density, lower calorific value (heating value), and higher viscosity as compared to petroleum diesel, giant palm biodiesel has a higher brake-specific fuel consumption (BSFC) than regular diesel. In order to compensate the inferred engine's low heating value, extra fuel is supplied, increasing the amount of specific fuel consumed. In contrast, according to Shojaeefard *et al.* (2013), the lower heating value of biodiesel compels the engine to burn more fuel in order to produce the same amount of power as a diesel engine. Moreover, Eze and Ejilah (2010) stated that the amount of fuel introduced into the cylinder for the desired energy input was greater for biodiesel. The results of this test confirmed that the lower heating value exhibited higher brake-specific fuel consumption and vice versa. This indicates higher fuel consumption per unit of power produced due to low combustion efficiency (Eze and Ejilah 2010). The findings are comparable to those of Zheng *et al*. (2008), who found a 23% rise in brake-specific fuel consumption (BSFC) when biodiesel was used as the fuel source. The higher BSFC of the biodiesel blends could be connected to the lower calorific value of biodiesel and its blends, on average by 12.5% of the net calorific value of methyl ester. The higher cetane number of biodiesel fuel and the change in injection timing were two additional factors cited by Buyukkaya (2010). Meanwhile, Sahoo *et al.* (2007) revealed no major difference in fuel consumption between methyl ester and petroleum-based diesel.

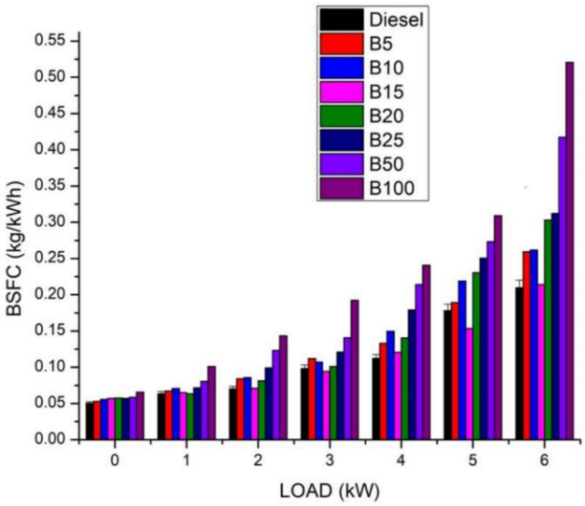

Figure 4 Brake specific fuel consumption variations for different biodiesel blends versus load.

Brake Thermal Efficiency (BTE)

The brake thermal efficiency of all fuel modes decreased as the load increased over the full range of loading circumstances. The BTE of giant palm biodiesel (B100) and biodiesel blends was lower than that of conventional diesel fuel, demonstrating the methyl ester's poor combustion properties as a result of its high viscosity and low volatility. Over time, it was discovered that the BTE from methyl ester was lower than that of regular diesel. The tendency is consistent with previous study (Chauhan *et al.* 2012; Panwar *et al.* 2010). Low heating value, high kinematic viscosity, poor spray characteristics, poor air-fuel mixture, and low volatility as a result of biodiesel from vegetable oils caused a drop in brake thermal efficiency (Nabi *et al.* 2009). Another factor could be the methyl ester's ignition delay, which initiates engine combustion before the piston reaches the top dead center. This can result in heat loss and decrease the engine's efficiency (Rao *et al.* 2007). Moreover, Karanja vegetable oil provided higher BTE at higher loading conditions and higher BSFC with the increase in blending ratio (Ashraful *et al*. 2014). While Canakci (2007) reported no significant difference between methyl ester and petroleum-based diesel, others have found that Karanja biodiesel blend offers higher BTE and BSFC compared to other biodiesels. Nonetheless, biodiesel combustion comes with low thermal efficiency, elevated emissions of nitrogen oxides (NOx), and carbon deposition issues (Ashraful *et al.* 2014). Figure 5 shows how the thermal efficiency of the brakes varies with loads for various giant palm biodiesel blend.

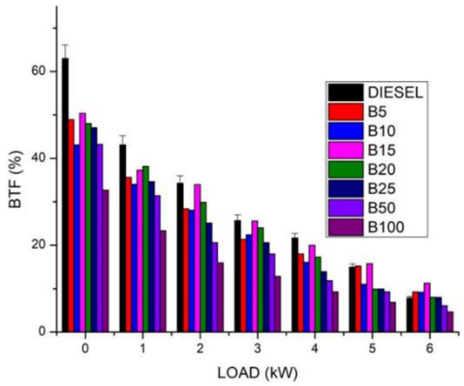

Figure 5 Brake thermal efficiency variation for different biodiesel blends versus load.

Brake Power

Figure 6 illustrates how the increase in load affects the brake power for various fuel blends. The figure shows that brake power diminishes for all loading conditions as the load increases. It was observed that the engine power for biodiesel and biodiesel blends is lower than that of the conventional diesel fuel when the brake power at various loads is compared with conventional diesel. It was observed from the graph that at lower blend ratio, brake power is close to conventional diesel fuel but lower. This drop in power output could be caused by the giant palm biodiesel's lower heating value. From the experiment, it was observed when petroleum-based diesel was utilized in the same engine, the power output decreased for B5 to B100 by 3.1–20%. According to Wan Ghazali *et al*. (2015), biodiesel blends have a little lower brake power than pure diesel (3.8–20%). This suggests that the brake power produced will decrease as the percentage of biodiesel in the blends increases. Aydin and Bayindir (2010) also concurred that using methyl ester as a fuel decreased engine output. The low heating value of methyl ester and the engine's incomplete combustion when utilizing biodiesel are the causes of the decline in output power. According to Oner and Altun (2009), the difference in engine power output between methyl ester and conventional diesel is insignificant. The justification offered was that engines provide fuels on a volumetric basis, and because methyl ester density is higher than that of diesel fuel, more methyl ester is supplied to make up for the fuel's lower calorific value (Qi *et al.* 2009). The larger spray droplets will be produced by the higher viscosity of the feedstocks and improve fuel spray penetration due to their greater momentum, enhancing air-fuel mixing (Nwafor 2004). In summary, a significant number of authors discussed power reduction, which was previously linked to high viscosity, the low calorific value of feedstock biodiesel, and incomplete combustion while utilizing biodiesel. In any event, higher fuel consumption would make up for the engine system's use of biodiesel, which has a lower heating value. Hence, the benefits of biodiesel from feedstocks will include decreased fuel leakages in the injection pumping system, advancement of the com bustion process, and higher lubricity of biodiesel.

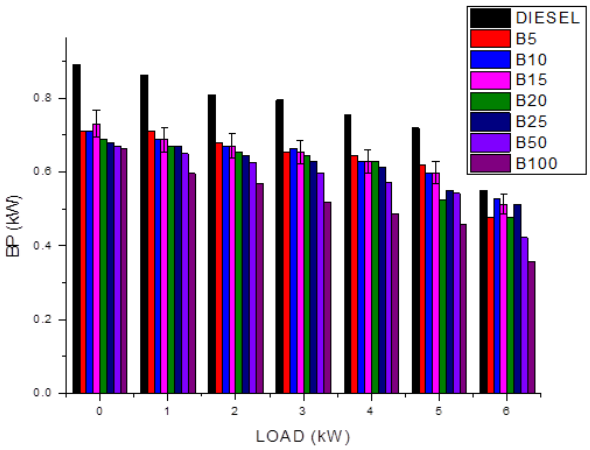

Figure 6 Brake power variation for different biodiesel blends versus load.

Brake Mean Effective Pressure (BMEP)

Figure 7 depicts the variance in brake mean effective pressure under different loading conditions of the engine for the various biodiesel blends. The graph demonstrates how BMEP reduces with increasing loading conditions. The conventional diesel's BMEP was higher than the BMEP of all blends under all loading circumstances. The findings were consistent with research done by Buyukkaya (2010), who examined the performance of a six-cylinder, four-stroke, turbocharged direct injection diesel engine when running at maximum load of 2000 rpm using neat rapeseed oil and its blends. According to reports, adding more rapeseed oil to the blends caused a decrease in the peak cylinder pressure. Therefore, the improvement in air-fuel mixing formation and atomization rate is directly related to the fuel's viscosity and volatility. Giant palm biodiesel and its blend's high viscosity and low volatility had an impact on the brake mean effective pressure. This implies that the brake mean effective pressure of the engine decreases as the biodiesel concentration increases. Other literature reported similar results are Senthil *et al.* 2005; Canakci *et al.* 2009; Devan and Mahalakshmi, 2009b. Devan and Mahalakshmi (2009) confirmed the same tendency when they evaluated diesel fuel with poon oil biodiesel at full load in single-cylinder diesel engines. They claimed that with regular diesel, B20, and poon oil, cylinder pressures of 67.5, 63, and 60 bar were reported. Pressure reduction with the expected effects of methyl ester viscosity on fuel spray, and reduction of air entrainment and fuel/air mixing ratio. However, the brake mean effective pressure of giant palm biodiesel fuels was lower than that of the conventional biodiesel fuel.

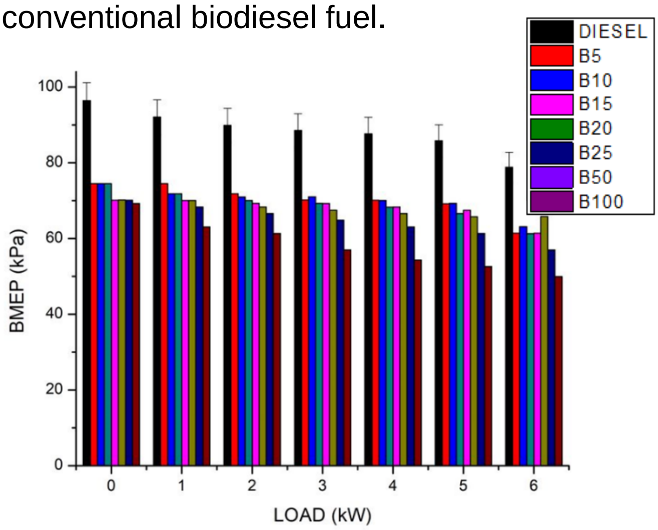

Figure 7 Brake mean effective pressure of different biodiesel blends versus load.

Engine Speed

The engine developed a speed for biodiesel blends that ranged from 750 to 650 rpm under the same conditions when utilizing conventional diesel at a full load (750 rpm). Also, the engine's speed at no load varied between 840 and 800 rpm for all samples made from giant palm biodiesel, whereas the tested engine's speed was 850 rpm. At all loading conditions, it was found that the engine speed dropped as the biodiesel concentration and loads increased. The relationship between load and engine speed is shown in Figure 8, which is consistent with previous research on biodiesel made from various sources such as canola, rapeseed, soybeen and beef tallow. Oniya and Bamgboye (2013) conducted tests on a single-cylinder 2.46 The engine speed remained constant for any increase in engine load after 75% of the full load for all the blends. However, the use of giant palm biodiesel resulted in a reduction in engine speed due to its low heating value, higher kinematic viscosity, poor spray characteristics, poor air-fuel mixture, and low volatility. High viscosity and poor volatility lead to poor combustion of the engine systems, which in turn results in low speed.

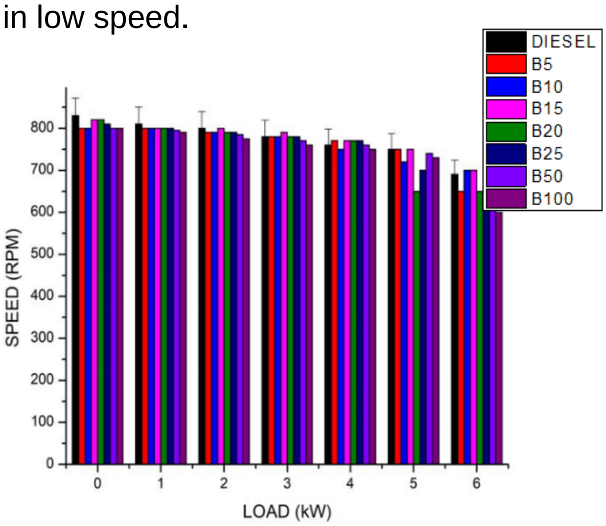

Figure 8 Speed variation for different biodiesel blends versus load.

CONCLUSION

A study was conducted on the production of biodiesel from giant palm seed oil, its characterization, and performance testing on a single-cylinder engine using various biodiesel blends at varying loads. The fuel characteristics of giant palm biodiesel and its blends, except for B50 and B100, were found to be identical to conventional diesel fuel and mostly within ASTM requirements. However, the short-term performance of a diesel engine fuelled with promising giant palm biodiesel showed a slight reduction in power output (brake power) and brake thermal efficiency, along with an increase in brake specific fuel consumption. The lower heating value (calorific value) of the biodiesel may be responsible for this reduction in power output, which ranged from 3.1 to 20%. This implies that the higher the biodiesel concentration in the blends, the lower the engine power generated. The increase in brake specific fuel consumption (BSFC) of biodiesel blends could be due to the low heating values when compared to petroleum-based diesel. Therefore, more quantity of biodiesel will be required to be injected into the combustion chamber for the desired energy output.

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The Effectiveness of Palm Oil Policies in Nigeria: An Experience from Malaysian Palm Oil Policies

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ABSTRACT

The tropical forest of West Africa is initially the first area where the oil palm was discovered before the 14th century. In particular, Nigeria was one of the places where this fruit was uncovered. Palm oil is ranked as the major vegetable oil in the world. In the 1960s, Nigeria was rated as the largest palm oil-producing and exporting country globally. However, the production was completely unsuccessful as a result of the government's failure to formulate good policies, while the local consumption increases. Oil palm production in Malaysia became a contributing sector to the national economy. It alleviates poverty, provides employment, allocates resources, generates incomes, and leads to economic development. Due to good and sustainable palm oil policies in this sector, Malaysia achieved global recognition. This paper's objective is to disclose the ineffective policies on palm oil in Nigeria and its sustainability in Malaysia. This paper is a qualitative design, it used primary and secondary methods. The primary method is based on a semi-structured interview, while the secondary method is based on documents. It adopted inductive thematic analysis for analysing interview data with the help of ATLAS.ti. This paper's finding is the unsuccessful palm oil policies in Nigeria and the sustainable palm oil policies in Malaysia. In conclusion, there is a need for Nigeria, to learn from the Malaysian experience.

Keywords: Oil palm, palm oil, sustained malaysian policies, unsuccessful nigerian policies

INTRODUCTION

Nigeria heavily depended on agriculture in 1960s, and later petroleum was explored which led to negligence of agricultural sector, particularly palm oil production which made Nigeria the major global palm oil producing and exporting country in 1960s. Nigeria now became dependent heavily on petroleum as major source of income. Palm oil is a top crop in the world for yielding more oil than other vegetable oils. Palm oil can be used naturally for a long time without any problem due to being an essential global diet. The increase in bio-energy demand and industries of oleochemicals, rapid growth in population, and increase in palm oil consumption led to its price to sustain. Nigeria is ranked as the most populous country in Africa with over 200 million people. It is the largest consumer of palm oil in Africa, it annually consumes almost three million metric tonnes of oils and fats, and in 2018 palm oil was the main consumed oil in Nigeria with 44.7%. In 2018, Nigeria is the major palm oil consumer in Africa, with the consumptions of 1.34 million metric tonnes. While its production of palm oil, has stagnated at

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only 1.02 million metric tonnes, and this resulted in supplying of 0.32 million metric tonnes as a deficit to bridge the gap (World Bank PwC analysis, n.d.). Nigeria was rated as the major global palm oil producing and exporting country in 1960s. But the production completely declined as a result of improper policies. Nigeria lost its position as a world leader in palm oil production to Malaysia (PIND 2011). Now it produces a meagre 1.7% of total world production which is insufficient for local consumption.

Oil palm is originally from West Africa brought to Malaysia in the late19th century. Palm oil also serves as a source of biodiesel. Most of the products parceled in a mall or supermarkets contained palm oil. Palm oil is good for human body health, and has more advantages than other vegetable oils. The palm oil consumption increased to 8 kg per person globally without decrease. The development of oil palm started in Africa and later shifted to Southeast Asia. According to statistics from FAO, Indonesia produces 53% of world production, while Malaysia produces 29%, Thailand 4%, Nigeria 2%, and finally Ecuador 1%. Palm oil is good in frying and it resists oxidation (Russell 2020). The problem that this paper tries to solve is: how Nigerian policies on palm oil became unsuccessful, and what are the policies that led to Malaysian sustainability on palm oil? Nigeria in 1960s was the largest palm oil producing country, but it was unsuccessful due to improper policies. Unlike in Malaysia whereby all the policies sustained and worked accordingly. The palm oil sector rose as the main source of income, which generates revenue, promotes economic development and alleviates poverty (Ismail 2013). The manufacture of palm oil in the global context enlarged in 2009 to 45.1 million tonnes if compared to 1980, as a result of supplying to key markets in the China, EU, Pakistan and India. Indonesia and Malaysia accounted for the 85% of the palm oil world production (Bek-Nielsen 2010). The main purpose of this paper, is to explore the unsuccessful Nigerian palm oil policies and sustainable Malaysian palm oil policies, and what experience Nigeria will learn from Malaysian sustainable palm oil policies. This paper is not comparing between Malaysia and Nigeria on palm oil; Malaysia is far better than Nigeria in terms of palm oil production. However, in 1960s Nigeria is ahead of Malaysia, but now it declined due to improper implementation of its palm oil policies. For Nigeria to recover its past glory on palm oil, it has to adopt a best oil palm production; and learn the experience from Malaysia oil palm production.

The main objective of this paper, is to explore the unsuccessful Nigerian policies on palm oil, and the sustained policies adopted by Malaysia on palm oil which led to its sustainability. This paper tries to bridge the gap and add to the body of knowledge so as to explore these unsuccessful Nigerian policies on palm oil and sustainable Malaysian policies on palm oil.

MATERIALS AND METHODS

Research methodology is used for data obtaining and analysing. Study is usually conducted for explaining a particular phenomenon (Creswell 2012). The research employed qualitative method for understanding the research problem. It is exploratory approach, and systematically used for data collection and analysis (Zhang and Wildemuth 2009). Qualitative document analysis generally relied on explaining the data, analyzing it and making a conclusion (Manheim *et al.* 2002). The study used both primary and secondary data. The primary data were collected from interviews, and the secondary data were collected from documents such as: journals, seminar papers, books, articles, dissertations, and magazines. The interview is open-ended interview. Six participants both from Nigeria and Malaysia were selected to provide their views. The interviewees from Malaysia responded based on this study face to face, while the interviewees from Nigeria responded through telephone. This study is non-probability which is purposive sampling (Creswell 2012). It used inductive thematic analysis for analysing the interview, it was immediately coded after it was conducted and analysed, and critically interpreted based on the information from the participants (Cohen *et al*. 2007). This study employed ATLAS.ti for interview data analysis. This software is used in qualitative study for analysing, coding, and organizing qualitative data (Zhang and Wildemuth 2009).

Oil Palm and Palm Oil

Oil palm is a tree originally from the west African tropical forest, it has been taken to Southeast Asia, it was grown to yield and develop agriculture. For many years, the oil palm was cultivated in Africa for food consumption. Trade in palm oil began during the Industrial Revolution, and it was used to lubricate machines. In 1917, it was firstly planted for commercial usage hundred years ago. Its massive plantations began during the technological advancement. Oil palm trees grow with sufficient heavy raining, sunshine and warm temperature. It grows in equator, which supplies warm temperature and sunshine. Malaysia and Nigeria have enough heavy raining, warm temperature, and tropical forests to grow oil palm trees). Palm oil is a vegetable oil extracted from mesocarp of oil palm fruit. It is used in making various food and non-food products (Anthony and Ogali 2014). Palm oil is a valuable vegetable oil, it is more economic and profitable than other vegetable oils in the world. Palm oil global demand for human consumption has increased. Palm oil is useful to make food products, while palm kernel oil is used to make non-food products such as soaps, cosmetics, and toiletries (MGCC 2017).

Literature Review on Palm Oil Policies in Nigeria and Malaysia

The areas with available lands for oil palm plantation in Nigeria were located in eastern region (presently Cross River State), but the majority of the areas were heavily populated with high density. In 1952 to 1962, thirty-six plantations were formed for oil palm and cocoa cultivations such as: Kwa Falls located in present state of Cross River; in 1955 it was renamed as the Eastern Nigerian Development Corporation (ENDC) (Kilby 1967). The ENDC and Eastern Regional Development Board (ERDB) seconded the government program to enhance the oil palm industry, whereby the majority of the farmers were small holders. The policy came into being coincidently at the time whereby, the marketing board made a decision of not accepting a low-quality oil produced by the farmers. The government provided the farmers with subsidy on seedlings and fertilizer for recovering the palm grove. Later, they were unfortunately given the subsidy very late. This delay impacted negatively on the farmers, and failed their target (Kilby 1967). The government dissolved the ENDC in 1976, and handed over the estates control to Cross River.

Later in 1982, the government shifted ENDC activities to the Agricultural Development Corporation. Mismanagement was discovered in the all plantations, and the estates were abandoned, this made the state government to regain its control (Schoneveld 2014). Agricultural sector declined to 26% in 1970s due to boom and high demand of petroleum in global market, it led government neglected agriculture and focused more on petroleum. As a result of this, unfortunately, palm oil production speedily declined. The Structural Adjustment Program was forcibly implemented in Nigeria, participation by government was discouraged, partnership between private and public sectors was encouraged, the oil palm estates were privatized to private individuals that could invest (Schoneveld 2014).

The government collaborated with the Vegetable Oil Development Programme (VODEP) on palm oil policy. It formulated the policy based on partnership between public and private sectors to develop palm oil production. The policy was unsuccessful due to poor funding, lack of frequent power supply, obsolete and local processing machines, and poor roads (Anyanwu *et al.*

2011) The smallholders were given 4120 ha in 2010 to plant oil palm, they utilized only 452 due to mismanagement, corruption, and lack of technical skill. This program became unsuccessful (Schoneveld 2014).

Malaysian national and international policies on sustainable palm oil came up with positive change, and expanded oil palm production with sustainable practice. They certified oil palm industries to continue with plantation on the degraded areas or previously converted. In Malaysia, the National Forestry Act (1984) has been formed and it helped government to formulate policies on conserving forest reserves and protecting forest estates (Government of Malaysia 2015). The National Commodities Policy (NCP) 2011–2020 was formulated for guiding palm oil industry in Malaysia, predicting oil palm areas expansion from 2011 to 2020 and to regulate the increasing rate of 1.6% annually (Government of Malaysia 2015. The Sime Darby became the major producer of palm oil in Malaysia in 2008. The company formulated a policy to prevent the expansion of new plantation on deep peat. The policy was later in 2013 applied on the entire new expansion on peat regardless of peat depth.

The Malaysian National Policy on the Environment is a policy which was formulated in 2002 to integrate the three essentials of sustainable development which includes: economic, social and cultural development. This policy was meant to conserve the environment and improve the Malaysians' life quality economically, socially, culturally and environmentally for sustainable development.

The National Biofuel Policy was a policy formulated to serve as one among the five Malaysian energy sources. This policy was meant to enhance the well-being of Malaysians and the people's prosperity. In addition, to reduce the Malaysian dependency and consumption of fossil fuels, to promote palm oil demand nationally and internationally, and to stabilize it's price. The National Policy on Biological Diversity 2016–2025 is a Malaysian policy formulated to direct and structure the procedure for conserving biodiversity for sustainable development and to solve the complicated challenges facing the biodiversity. This policy serves as a plan for Malaysian response to the agreement on Biological Diversity 2011–2020. The policy was empowered to achieve major five objectives which are: to reduce putting pressure on biodiversity, to protect species and genetic diversity, to safeguard ecosystems, to ensure fair sharing of biodiversity benefits, and build capability for all shareholders. These different policies mentioned above are the policies that supported the major Malaysian sustainable policies.

RESULTS AND DISCUSSION

Unsuccessful Nigerian Policies on Palm Oil

This explains the unsuccessful palm oil policies that were adopted by state and federal governments in Nigeria. These policies were meant to develop palm oil production. Unfortunately, the policies became unsuccessful due to improper implementation.

The Plantations, innovations and settlements policies from 1950s to mid-1960s

During the colonial government in 1952, the entire economic activities and development were based on regional governments of north, east and west. The eastern region government recovered the anti-plantations policy. It came into being at the time of rapid growth of oil palm, the plantations in Malaysia and Indonesia due to competition to expand oil palm plantations. It was witnessed that, good seeds yield more fruits than before with good mills 95% of palm oil could be extracted from the fruits instead of 50% which is traditionally extracted (Udo 1965). After independence in 1960, there was a new agricultural innovation which was regarded as agricultural revolution, declared by first premier of eastern region.

There was an establishment of five ENDC plantations in 1964 for planting 47,000 ha of oil palm tree (Kilby 1967). The ENDC plantation was certified in 1966 to plant additional 60,000 ha (Schoneveld 2014). During that time, the present area of Cross River state was the major area which contained the 80% of oil palm plantations in Nigeria. Many companies from Europe paid their attentions to this area and established oil palm plantations. Later, these European companies relocated to other countries due to low price from Nigerian marketing board (Udo 1965).

The Nigerian government policy was implemented in form of African socialism for funding agricultural sector, improving farming and formation of farm settlements. The farm settlements were located in eastern region, and proposed oil palm farming to be mixed with rubber and food crops as the main priority and emphasis (Korieh 2010). This farm settlement policy became unfamiliar to the local farmers due to its restriction to their traditional way of daily life. The farm settlements entirely developed crops for export and little for local consumption. This led to increase in production of cash crops, and the farmers with interest and motivation in farming were not positively considered by the government. This farm settlement has similarities from Israeli scheme, and Malaysian FELDA. In Nigeria, the government collectively engaged oil palm farmers, trained and assisted them with seedlings. However, the farmers preferred to process oil palm fruits traditionally rather than to be processed in the mills due to high transport cost compared to Malaysian smallholders' settlements, and the policy became unsuccessful (Kajisa *et al.* 1997).

Military/Civil rule policies from 1967 to 1999: Civil war, petroleum and the SAP

Nigeria faced a civil war which started in 1967 and ended in 1970 due to petroleum discovery in the eastern region. The eastern region was the main dominant area of oil palm plantations, and the war took place in this region which spoiled oil palm plantations and interrupted its boom. This led to private estates became out of control and collapsed entirely, and led to decline in palm oil and palm kernel oil exports, and decline in economic development (Schoneveld 2014). Due to the civil war and petroleum boom in 1970s, Nigeria faced a problem of agricultural decline, and trade in palm oil and palm kernels speedily died. Military regimes ruled Nigeria since 1967 up to 1999 with different policies to improve agriculture, but food imports sustained to be rising (Kajisa *et al.* 1997).

The Structural Adjustment Program (SAP) was implemented in Nigeria in 1986. This program devaluated Naira (Nigerian currency) with 80%, it spoiled the urban areas salary level, and inflated the price of agricultural yields. The SAP hidden policy led to the abandon of palm oil marketing board, and spoiled the Nigerian economy by declining palm grove plantations. The Nigerian economy was spoiled due to SAP implementation, it gradually inflated the necessity goods price, and threw the economy in decadence. The food price could no longer be controlled, and doubles gradually without government intervention and control. The big oil palm plantations were owned and controlled by retired officers' wives through illegal and improper way. This led the policies became unsuccessful (Von-Hellerman 2007).

Civilian government policies from 1999 to present-day

There was a transitional government in 1999 from military regime to civilian rule. The fourth president was Obasanjo; he was elected for two-term-tenure from 1999 to 2007. The policy of privatization was sustainable under the federal government, whereby the resources owned by a state were privatized. The private sector played a vital role on agriculture (Iwuchukwu and Igbokwe 2012). During the 1999 to 2007 under the civil government, there was a programme on poverty alleviation to boost agriculture to a higher level which it had before the oil discovery. The main target was to achieve food security within the country so that poverty and food insecurity should be eradicated. The government came up with the Vegetable Oil Development Program (VODEP) to develop palm oil production in Nigeria. It formulated a policy to make partnership between public and private sectors to expand oil palm production. This policy became unsuccessful due to lack of enough funds, insufficient frequent power supply, locally made and outdated processing machines, and poor roads (Anyanwu *et al*. 2011). The commercial smallholders were given 10 to 20 ha from the government empty lands together with planting materials in 2010. They used only 452 ha out of 4120 ha given to them. This programme became unsuccessful due to smallholders' mismanagement, corruption, and improper technical skills (Schoneveld 2014).

This study used semi-structured interview to investigate the unsuccessful Nigerian policies on palm oil. These six participants are from Nigeria, they have expertise in this area, and responded to this interview. All are Nigerians with the age grades from 40 to 50 years, and they are professionally educated. First participant is a chief agriculture superintendent; he holds Master degree. The second participant holds Master's degree and research officer one. The third participant is a senior technical officer in production and processing sector, he is a degree holder. All are from Nigeria Institute of Oil Palm Research (NIFOR). Participant four is a degree holder and senior quality assurance in production and processing sector from West African Soil Industrial Limited (WASIL), Nigeria. The fifth participant is from Northwest University, Kano. He is a PhD holder and lecturer. And the sixth participant is a PhD holder, and lecturer from Federal University, Gashua, Yobe State, Nigeria. This selection is based on the participants' will and knowledge. These interviewees were interviewed on the unsuccessful Nigerian policies on palm oil.

The following figure represents the result from the interview. From the above Figure 1, the first participant said that, Nigerian government has policies on palm oil such as: giving loans to oil palm farmers, but most of the farmers are not given the loans from government, it is offered to non farmers who do not refund money due to politics. The second participant explained that government have good policies on how to improve palm oil sector in Nigeria, but the policies are on paper and not implemented due to lack of proper funding. That's why the policies failed. The participant three exposed that the main problem, is lack of good government policies due to corruption. In reality, corruption destroyed everything in Nigeria. The fourth participant highlighted that, Nigerian government do not give much emphasis on palm oil, that's why the palm oil policies are not influential. The participant five explained that, the palm oil policies are on paper, but not on real ground. The real farmers are small scale farmers making the 70% of the farming. There is no successful policy which will encourage them to transform from substance farming to commercial farming. The sixth participant confirmed that in Nigeria, there are a lot of palm oil policies on paper which are very weak. They will neither be implemented or partially implemented. Because the agricultural sector was neglected, that's why the palm oil policies became unsuccessful. All the participants confirmed that, Nigerian policies on palm oil are unsuccessful.

Sustained Malaysian Policies on Palm Oil

The MPOB is a government influential institute, take care of conducting research production growth and industry rules and regulation. This institution develop oil palm production, it improves the quality of the production, and it formulates policies on export for global markets. These policies concentrated to ETP and formulated to make Malaysia a country with high income in the year of 2020. In the year 2020, oil palm as a significant to GDP, to contribute USD 57.4 billion to Gross National Income (GNI).

First Industrial Master Plan (IMP1)

As a result of implementation of Malaysian Industrial Master Plan (IMP), the

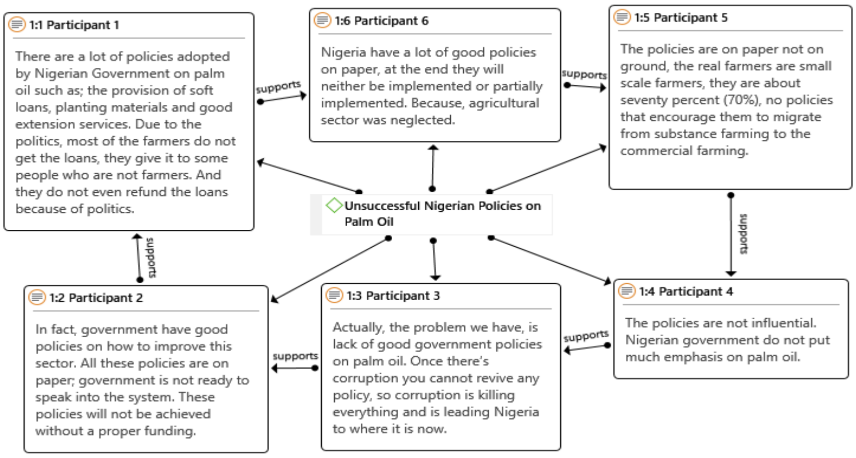

Figure 1 Unsuccessful Nigerian policies on palm oil.

processing of oil palm in the upstream and downstream obtained supports from government different policies. First Industrial Master Plan (IMP1) came into being in 1986 to provide a developmental structure in Malaysian production. The IMP1 planned to shift the economy from agricultural and primary stage to the more of production. IMP1 itemized twelve subsectors of the industry as part of palm oil subsectors to be developed. IMP1 gave much emphasis on refining the palm oil and fractionating it so as to improve and develop different sectors of the value chain as well as competing in the global markets (Rasiah and Shahrin 2006).

The Second Industrial Master Plan (IMP2)

The Second Industrial Master Plan (IMP2) came into being to cover from 1996–2005 for developing the sector and enhance the industrial linkages, increase productivity and value-added activities as well as sufficient and sustainable supply of raw material through imports (Rasiah and Shahrin 2006). However, in this time Malaysian processing capability surpassed the CPO supply. The IMP2 extended to Sarawak and Sabah and presented inducements for industries of agro processing and labour. The processing in down-stream has been encouraged by the IMP2 to add value and focus on mechanisation and biotechnology such as genetic engineering, mass tissue culture and cloning (Rasiah and Shahrin 2006).

The Third Industrial Master Plan (IMP3)

The Third Industrial Master Plan (IMP3) came into being to cover from 2006–2020. The emphasis to be given on the downstream manufacturing activities, and add value on the products by conducting research and develop comercial sector. Also to collaborate between oil palm industries and government research agencies. In 2010, the Economic Transformation Programme (ETP) has been introduced by the Malaysian government, which planned for economic policies of 10 years, for energising Malaysia to be a country with high income in 2020. The industry of oil palm has achieved special recognition for emerging the economy of Malaysia under the 12 National Key Economic Areas (NKEA). The sector of palm oil under NKEA, was to improve the productivity in the upstream, increase downstream enlargement as well as focus on the oil palm industry sustainable development (May 2012). ETP's 2012 Report on Eight Entry Point Projects. I. Speeding up replanting of new oil palm; II. Enhancing fresh fruit bunches; III. Increasing worker output: IV. The oil extraction rate (OER) Improvement; V. Intensifying biogas amenities with the mills; VI. Growth of biobased chemicals and high value oleoproducts; VII. Commercializing second-generation biofuels; and VIII. Accelerating health and food development.

This study used semi-structured interview to explore Malaysian sustainable policies on palm oil from the view of six Malaysian participants.

The participants age grade started from 40 to 50-year-old. They are professionally educated. Participant one is holder of Master degree, and Deputy Director-General Services, Malaysian Palm Oil Board (MPOB), Ministry of Primary Industry. Participant two is a Master degree holder, and he is Manager Research Development from FELDA Global Ventures Holdings Berhad (FGV Holdings Berhad), Malaysia. The third participant is a Master's holder and Director, Profes Lipid Sdn. Bhd., Malaysia. Participant four holds Master's degree, and he is Head of Marketing from Oliq Trade Sdn. Bhd., Malaysia. The participant five is Professor and Dean Faculty of Social Sciences from University of Sultan Zainal Abidin, Terengganu, Malaysia. Participant six is an Associate Professor, Faculty of Bio-resources and Food Industry, from University of Sultan Zainal Abidin, Malaysia. There panelists were selected based on the participants' knowledge and will of participating in this research paper. From Figure 2, the participant one highlighted that, Malaysia achieved sustainability due to good policies on palm oil. He further explained that, Malaysia diversified from tin and rubber previously, instead to depend only on rubber and tin with low price. It moved into industry whereby it could achieve more values, then the industry was given self-control, but with compulsory rules and regulations to follow. The second participant explained that, the Malaysian policies on palm oil are: RSPO, policy on environmental conservation, and policy for the employees. The government now enforces full scale and would be compulsory by 2021. The participant three stated that, Malaysia achieved sustain-ability on palm oil due to sustained policies. Malaysia has given much emphasis on the Malaysian Sustainable Palm Oil (MSPO) that, all the palm oil they produce is sustainable. The fourth participant said that, Malaysia have a lot of policies and a lot of certifications. Experts are called to join the board for palm oil trip. The fifth participant exposed that, Malaysian government have policies on palm oil which includes: capping of oil palm cultivated area up to 6.5 million acres, stopping the planting of oil palm in peat land areas, strengthening the regulation of existing oil palm cultivation on peat land, and ban the conversion of forest reserved areas for oil palm cultivation. Participant sixth dis-coursed on the Malaysian master plans which are the three main plans that diversified the economy. These are: First Industrial Master Plan (IMP1) from 1986 to 1995 to shift the economy from primary product-based to the manufacturing sector, Second Industrial Master Plan (IMP2) from 1996 to 2005 to develop the sector, and Third Industrial Master Plan (IMP3) much emphasis on the manufacturing activities from downstream as well as value-added products through research. All the three participants confirmed that, Malaysia achieved sustainability on palm oil due to good and sustained policies.

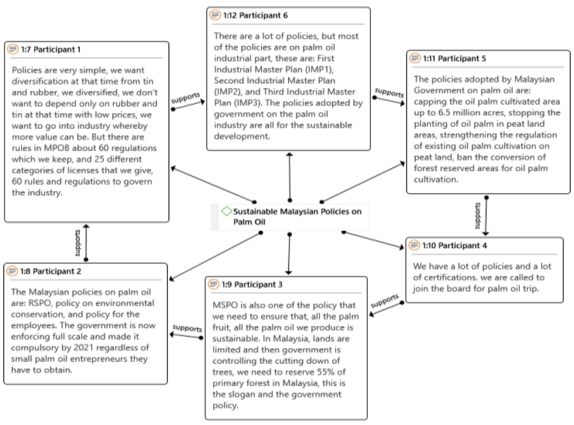

Figure 2 Sustainable Malaysian policies on palm oil

CONCLUSION

This paper briefly explained palm oil background in Nigeria and Malaysia, oil palm and palm oil. It exposed unsuccessful palm oil policies in Nigeria from both military and civil governments for diversifying Nigerian economy particularly palm oil. While in Malaysia, the palm oil policies are well formulated and implemented. The policies sustained due to good diversification and sustainability such as: IMP1, IMP2, and IMP3. The contribution of this paper, is to show the unsuccessful palm oil policies in Nigeria, and its proper formulation and sustainable implementation in Malaysia, and how Nigeria will learn from Malaysian experience through its palm oil policies. Nigeria have to really learn a lesson from Malaysian palm oil policies, to diversify its economy and to allocate huge amount of their annual budget to agriculture. There is need to have more investment on palm oil internally and externally, especially from Malaysia. Malaysia have to come up with more policies to protect the image of palm oil due to the global challenges. Malaysia have to look for more lands especially in Nigeria to expand its plantations due to limited land in Malaysia. If Nigeria can adopt modern farming based on global practices and to improve agricultural sector, especially palm oil, it will revive its past glory on palm oil production. Nigeria has to formulate good economic policy on palm oil, and implement it accordingly bit by bit. Malaysia was a country that Nigeria assisted with the oil palm seedlings, but it utilized it and used the golden opportunity and developed as the major second global palm oil-producing and first exporting country. At the same time, Nigeria still serves as the palm oil net importer, while it produces a meagre of 1.7 which is not enough for local consumption.

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Insights Into Oil Palm Yield Under Seasonal Rainfall

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ABSTRACT

Young oil palms produce many small fruit bunches. With age, bunch number (BN) declines but single bunch weight (BW) increases more than the BN decline, raising its yield (FFB, or BN*BW). In a long-term trial in seasonal Southern Thailand, the age trend accounted for 81% of the variation in BN. With irrigation, BN increased 34%, and BW 5%, and the age trend accounted for 90% of BN variance. It was 98% for BW with/without irrigation. Besides age trends, the regular December–March dry season, despite irrigation, combined with intrinsic alternating sex cycles resulted in annual cycles in BN and BW. The BN cycle was more marked in younger palms whose rooting is shallower. The BW cycle persisted throughout, albeit at lower amplitude than BN. Female abortion after high production resulted in a BN semi-annual cycle, with peaks in Mar/Apr and Sep/Oct. A similar cycle for BW in older palms, with peaks in Dec–Feb and Jun–Aug, arose from fluctuating pollination. A three-year cycle in BN of unirrigated palms may be due to exhaustion/replenishment of carbohydrate reserves. Underripe harvesting, causing more yield in a month, and a dearth after, resulted in a 2-month cycle for BN.

Keywords: irrigation, oil palm, Thailand

INTRODUCTION

The oil palm starts bearing (~2–3 years from field planting) by initially producing many small bunches, e.g., 15–20 bunches/year of average 3-5 kg weight. With age, the bunches increase in size but the number decreases, e.g., plateauing at 1–3 bunches of 40–60 kg at 20–30 years old, the end of its economic life. Average fruit size is largely unaffected. While this is the intrinsic nature of the palm, the enquiry is whither genetic and environmental effects. The question(s) was explored from 174 months (14.5 years) of yield (bunch number, and total and average single bunch weight) of individual progeny palms from first harvest at two years after planting. In this paper we report on aggregate behaviour. Progeny differences are discussed in a follow-up companion paper.

MATERIALS AND METHODS

The 1999 trial comprised 13 DxP progenies grown with/ without irrigation at Univanich's TOPI estate (8°30' N, 98°50' E) in the Plai Phraya District of Krabi Province, South Thailand. The region typically

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experiences an annual 3–4-month dry season as in the rainfall records of the estate (Figure 1). Over a year, the rainfall is generally adequate for oil palm, if sub-optimal, but was higher in the last five years of the trial (Table1). In the irrigated block, each palm was drip irrigated at 300 L/day in the dry season (January to April) as per Palat *et al*. (2008).

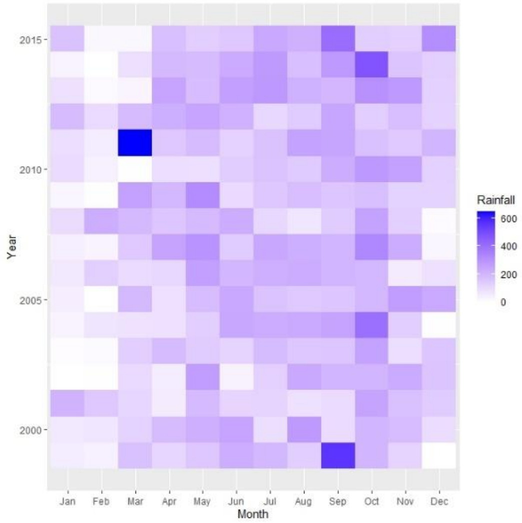

Figure 1 Monthly rainfall at trial location 1999–2015.

There were 234 experimental palms in the irrigated block and 468 in the unirrigated. Harvesting started in July 2001, 24 months after planting, and was done every 10–15 days, as per the industry norm. At each harvest, every bunch was weighed, and the data aggregated monthly. In brief, the bunch number (BN) and bunch weight (BW) were recorded from which could be derived the monthly FFB yield (BN* average BW). While yield in the first three months for the unirrigated area was recorded as zero from delayed bearing, if there was no yield from a particular block in subsequent months, i.e. BN =0, BW and FFB were recorded as 'NA'. There were seven such records in the irrigated data and four in the unirrigated. The subscripts 'irr' and 'nirr' denote the irrigated and unirrigated data.

The 174 months of continuous yield records of the two blocks were examined graphically and as time series data, i.e. a sequence of observations ordered over time, using R–a programming language for statistical computing, data visualisation and data analysis. Besides based on R, the following programme libraries were involved: tidyverse for data preparation, ggplot2 and lattice for data visualisation and astsa, rSSA and multitaper for time series analysis (TSA). Pretesting showed the time series data to be neither stationary nor ergodic (test results not shown) and this was considered throughout the analysis and interpretation, particularly the choice of programme libraries for TSA. There were a few outliers, but not removed as they actually occurred, i.e. not artifacts like recording errors (Sarkar 2008).

The primary analytical approach was to decompose and rebuild the time series by Singular Spectrum Analysis or SSA (Elsner and Tsonis 1996, Golyandina *et al.* 2001). SSA is data-adaptive and non-parametric, affording data representations that minimise global reconstruction error without the need for underlying statistical models. Unlike classical regression, efficient results are not premised on the stationarity, linearity, or normality of the data. Besides revealing trends, the method is superior to conventional techniques for detection of relatively weak and low frequency oscillations. As FFB, BN and BW trends with age are well known in oil palm, our primary interest was in deciphering seasonal effects with/without irrigation. Like PCA, but with wider applications, SSA decomposes data but into a number of time-shifted segments, sub series or components (Wickham 2016).

The correlation matrix estimated after embedding the single-dimension time series into its multi-dimension delayed coordinates or lagged vectors is eigen decomposed. In practice SSA consists of the following four steps: 1) segmentation of the time series into time-shifted or lagged components based on a defined time or window length. 2) their singular value eigen decomposition or SVD so that the first component accounts for the largest possi ble variance followed by succeeding lesser components, each separable from the pre-

Table 1 Annual rainfall (mm) and raindays at trial location.

Year	1999	2000	2001	2003	2004	2005	2007	2008	2009	2011	2012	2013	2014	2015
Rain-fall	1995	1880	1716	1624	1915	1938	2198	1834	1842	2480	2114	2263	2265	2134
Rain-days	141	120	140	108	129	117	138	119	110	148	135	129	143	131

ceding and accounting for the highest of the remaining variance. SVD is widely used for reducing and denoising multi-dimensional data in machine learning, image and facial recognition from pixel capture, sound and voice recognition from digitised sound, natural language processing, etc. 3) a regrouping based on importance and separability of the components. High singular value single eigentriples mean trends, eigentriple pairs with close singular values denoting periodic components while a gradually decreasing sequence of singular values are typical of pure noise series. 4) a reconstruction of the time series from step (3) above. How well the reconstruction mirrors the original time series provides the confidence for forecasting. The slowly varying trend components may be intrinsic to the crop or stem from systemic changes in the growing environment. The trends may also change significantly at times. We used the R programme library 'astsa' to show these breakpoints. Oscillatory periodic or cyclical components, on the other hand, are often driven by seasonal environmental influences, endogenous cycles from hormonal or carbohydrate status and regular human interventions. Spectral profiling can aid discovery of periodic components and their importance. A high spectral density at a particular frequency implies periodicity at that frequency. However, with natural data, poor resolution and leakage can complicate their discovery. As a safeguard, we augmented the spectral analysis provided by Rssa with multitaper methods (MTM). Still, with natural data, removing trends and cyclicals will leave many non-independent components, each accounting for a small part of the variance. These are bulked and reported as residuals here but as 'noise' in other physical phenomena, particularly signal processing.

Variants of SSA have been developed and used for many types of temporal, spatial and sound series (Golyandina *et al* 2018 for examples). Given that BN and BW in oil palm show strong time trends, we opted to use a 2-step Sequential SSA variant; a first to isolate the trend and then repeat the SSA for the de-trended time series for cyclical components. The method is detailed below for BN_{nirr} and BW_{irr}, two contrasting traits in different environments, followed by summaries for both traits in both environments (Rahim *et al.* 2014).

RESULTS AND DISCUSSION

Defining Trends

FFB and BW rose rapidly from start until about the 9th year after planting (Figure 2). Thereafter FFB plateaued while BW continued to increase, albeit at a slower pace. BN, on the other hand, was highest at start of bearing and then declined, the converse of the BW trend. It plateaued more gradually and, at any age, fluctuated more than BW (grey shaded area straddling the trend lines in Figure 2). Note that the low initial BN, of non-irrigated palms, especially in the first three months, is an artifact from not all the palms starting to yield together. Unsurprisingly, irrigated palms were more consistent in their start of bearing. The BN decline was immediate and continuous, contrary to Corley & Tinker (2016) who found the onset only after 6–10 years of bearing. However, the faster increase in BW contrived a rising FFB. Only after ~10 years of bearing, with BW ~20kg, did the decline in BN begin to offset the increasing BW, resulting in a plateauing FFB. There is debate whether FFB declines thereafter, albeit very gradually. A simple regression of FFB on age, suggests

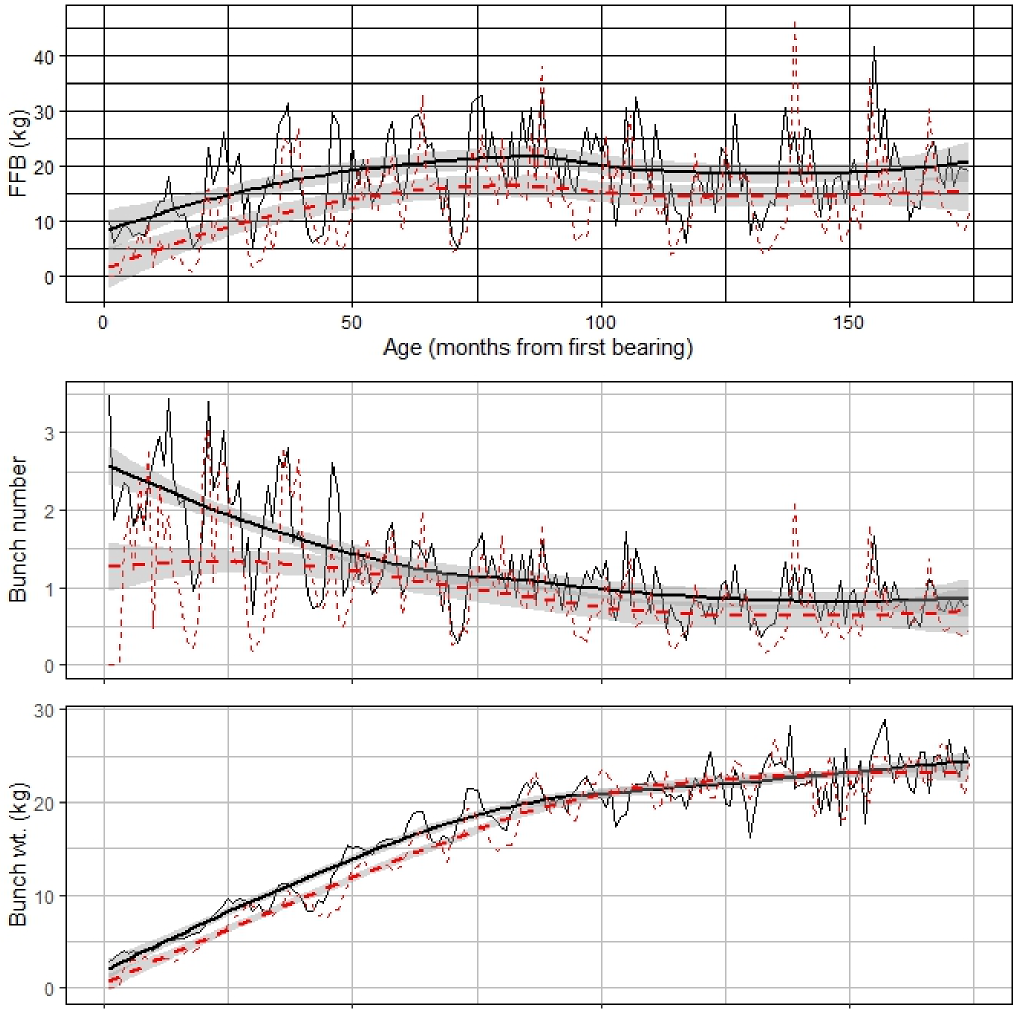

Figure 2 Trends in monthly FFB, BN and BW throughout trial for irrigated (solid line) and unirrigated (dashed line) palms. Straddling grey area is the 95% confidence interval.

that this was not so, until at least the end of the trial, although the areal yield may have done so from increasing dead palms and more missed bunches from the tallish palms.

Irrigated and Unirrigated

Throughout the trial the irrigated palms produced ~34% more bunches, which also averaged ~5% larger, resulting in a yield gain of ~38% (Figure 1). However, from the 8th year of bearing the higher yield only resulted from higher BN as both the irrigated and unirrigated BW had converged. This is probably due to the more robust root system in the older palms tapping into deeper soil water as against mainly the surface moisture previously. As the alleviation of water stress may have helped in the BW convergence, it is likely that better rainfall would be useful, and drought the converse. Interestingly, FFB fluctuated in tandem between the irrigated and unirrigated palms throughout the trial, i.e. irrigation did not dampen it. So other factors may be involved as well, such as the palm carbohydrate status.

Breakpoints

Analysis of the trends, using the R package astsa, (identifying structural breaks using piecewise AR models) revealed break points in both BN and BW (Figure 3). There was a structural change in BN after about the 4th year of bearing in irrigated palms and a year sooner in the un-

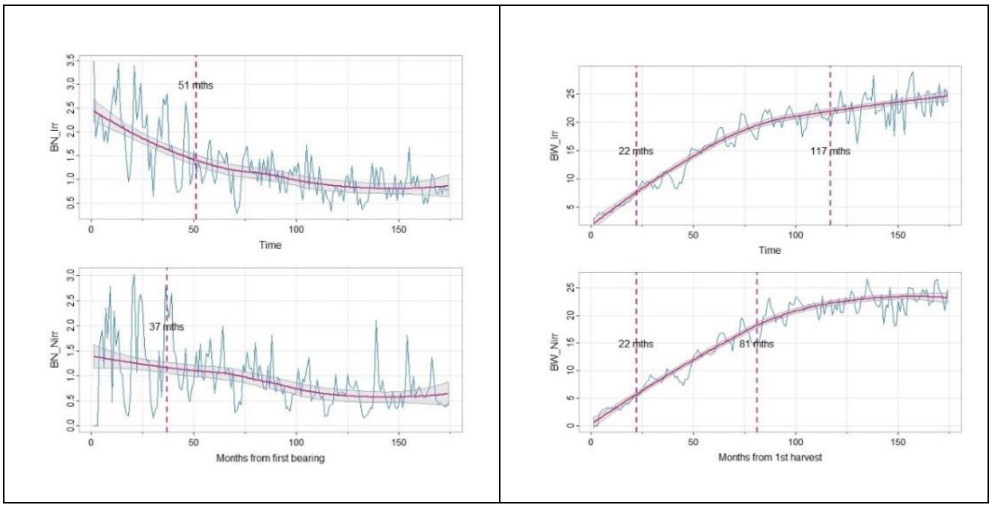

Figure 3 Breakpoints in BN (R) and BW (L) trends for irrigated (irr) and unirrigated (nirr) palms.

irrigated palms. These breakpoints are when the variability in monthly bunch number begins to reduce. The bunch weight trend stabilizes even sooner, after about 2 years of bearing, in both environments and a further change at the plateauing stage. This latter is sooner in unirrigated palms, at seven years after bearing while in irrigated palms BW continues its steep increase till about the 12th year of bearing. The trend slope is gentler thereafter in both. No breakpoints were found in the FFB trends of both irrigated and not irrigated palms the inverse relationship between BN and BW negating their respective breakpoints.

Singular value decomposition and spectral profiling

Screen plots of the singular values of 84 lagged components for BN_{nirr} and BW_{irr}, respectively, are shown in Figure 4. We chose a long window length divisible by 12, hence 84 ≈ ~174/2, to capture any long-term periodicity, while recognising the potential major influence of annual rainfall seasonality. The y-axis of singular values is the explained variance for each component. Clearly, the first component accounts for, by far, most of the variance, particularly for BW_{irr}, and the first 10 for > 90% of the variance for all traits (Table 2). This is common with most natural time series. Where two components have the same or similar singular values they point to periodic components as discussed below.

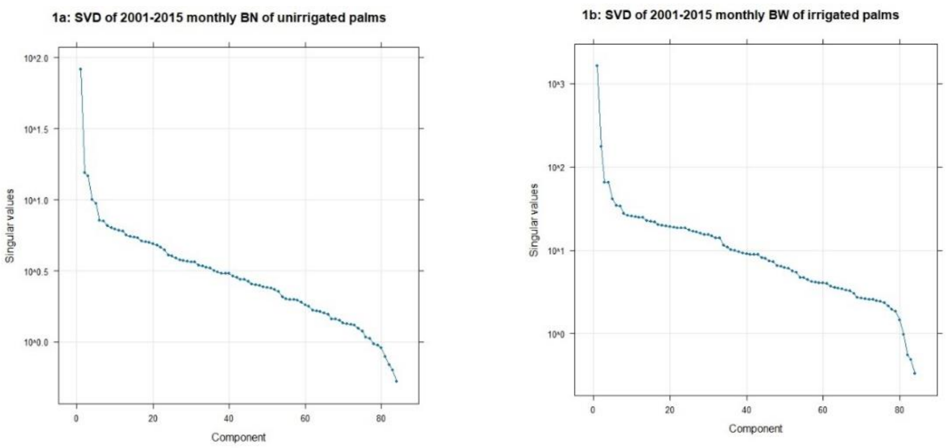

Figure 4 Screen plots of singular values of components from SVD of BN_{nirr} (1a) and BW_{irr} (1b).

Table 2 Proportion (%) of time series variance accounted for by first 10 components from SSA.

Trait		Component										
		1	2	3	4	5	6	7	8	9	10	∑
Not irrigated	BN	81.2	2.85	2.52	1.20	1.05	0.61	0.60	0.51	0.48	0.46	91.5
	BW	97.8	1.38	0.10	0.10	0.07	0.05	0.05	0.04	0.03	0.03	99.7
	FFB	80.8	1.87	1.79	1.35	1.07	1.04	0.84	0.82	0.59	0.58	90.7
Irrigated	BN	89.6	1.37	1.36	0.49	0.49	0.35	0.32	0.31	0.31	0.27	94.9
	BW	98.0	1.11	0.16	0.16	0.06	0.04	0.04	0.03	0.02	0.02	99.6
	FFB	88.2	1.14	1.10	0.76	0.64	0.63	0.56	0.53	0.39	0.26	94.2

Figure 5 shows the patterns of the first 12 eigenvectors of the SVD of BN_{nirr} and BW_{irr}, respectively, and their relative contributions to the decomposition. The slowly varying lines denote trends while the more sinusoidal ones suggest periodicity. While the trends are well known in oil palms, the high proportion of variance due to them was still revealing, particularly for BW. In practical terms, the age of palms is the *sine qua non* for estimating BW with one caveat. The BW decomposition shows two trends, albeit with the second accounting for only a small proportion of the variance. The implications of this second trend, as also found in BW_{nirr} decomposition, are discussed below. How well the components are separated, i.e. are not auto correlated, is seen from the weighted correlation matrix (Figure 6) with possible *r*-values from white (*r* =0) to black (*r*=1). The leading single eigentriple(s) describes the exponential trend, while the pairs of subsequent eigentriples correspond to the harmonics, and large 'sparkling' squares indicate white noise. For both BN_{nirr} and BW_{irr}, and, indeed, all traits, the first component, i.e. the trend component, is completely separated from the rest justifying its removal for sequential SSA of the remaining variance. Component 2 of BW_{irr}, which is not a periodic component as seen from the scree plot, is also well separated from the others, except for a correlation (*r*=0.23) with component 5. However, as this value is rather low, this 2nd component was also removed from the repeat SSA of BW_{irr}. In sequential SSA, the

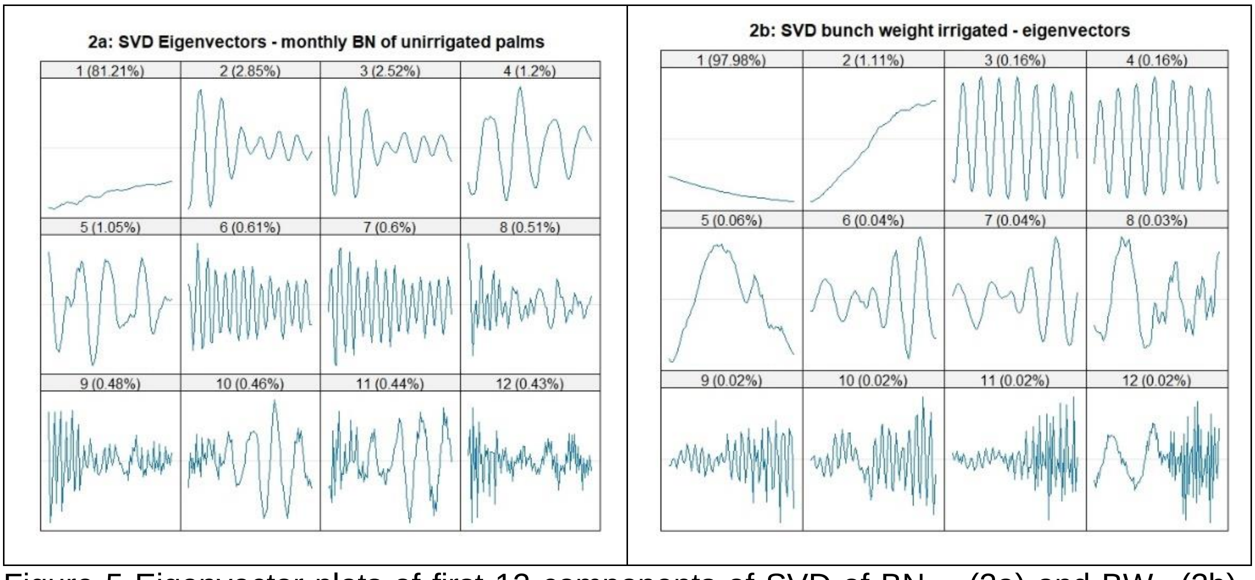

Figure 5 Eigenvector plots of first 12 components of SVD of BN_{nirr} (2a) and BW_{irr} (2b). Values in parenthesis are relative contributions in the decomposition.

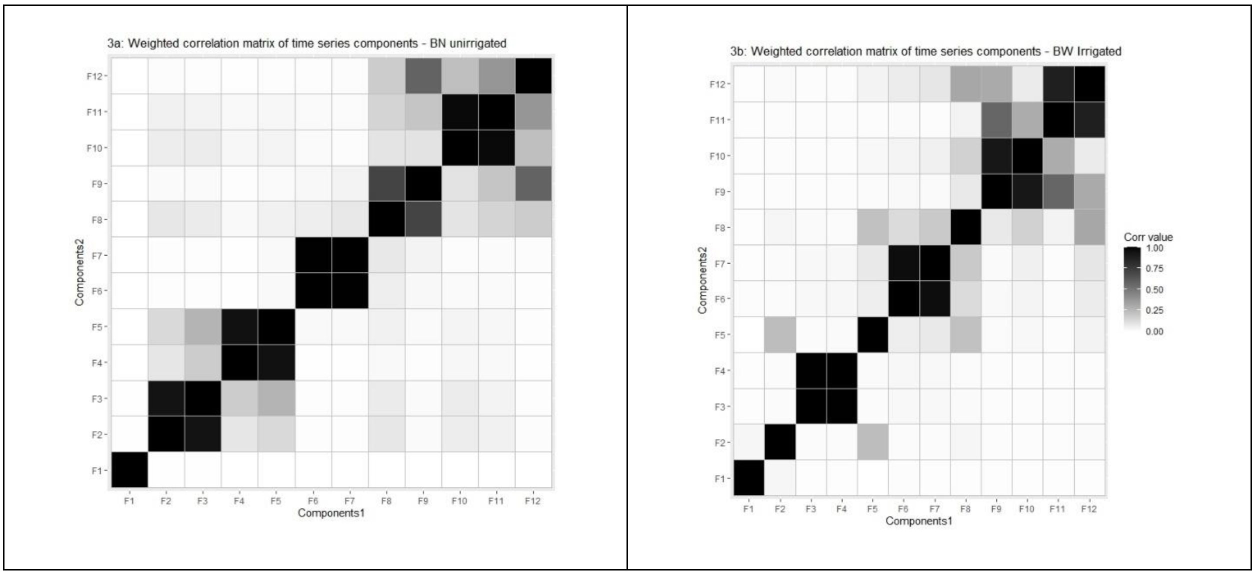

Figure 6 W-correlation matrix of first 12 components of SVD of BN_{nirr} (3a) and BW_{irr} (3b).

residuals, after removing the trend component(s) from the original time series, are decomposed anew to extract the periodic or cyclical components. Figure 7 is the scree plots of the detrended series for BN_{nirr} and BW_{irr}, and attention is drawn to the plateaux. A plateau of two components, or eigentriples (ET) of equal value, denotes a periodic series. For BN_{nirr}, there is a clear plateau at components 5 and 6 with SVD sigma values 7.2 and 7.1, respectively. There are two other plateaux, albeit less smooth, at components 1 and 2 (σ=15.4 and 14.6) and at components 3 and 4 (σ=10.1 and 9.4). For BW_{irr}, there are two clear plateaux; at components 1 and 2 and at components 3 and 4. Their sigma values were 65.6 and 65.3 and 34.2 and 33.5, respectively. Pairwise scatterplots of the singular vectors can reveal the eigentriples for harmonic or periodic components (Figure 8). Scatter-plots of pure sine and cosine functions of equal frequencies, amplitudes, and phases are circular. However, if P= 1/w is an integer where w is the frequency, then the scatterplot points are the vertices of a P-vertex polygon. A clear example is the hexagon from the scatterplot of eigentriples 5 vs 6 in Figure 8 (5a); the six vertices of the hexagon denoting a semi-annual periodic component. However, as seen in the next section,

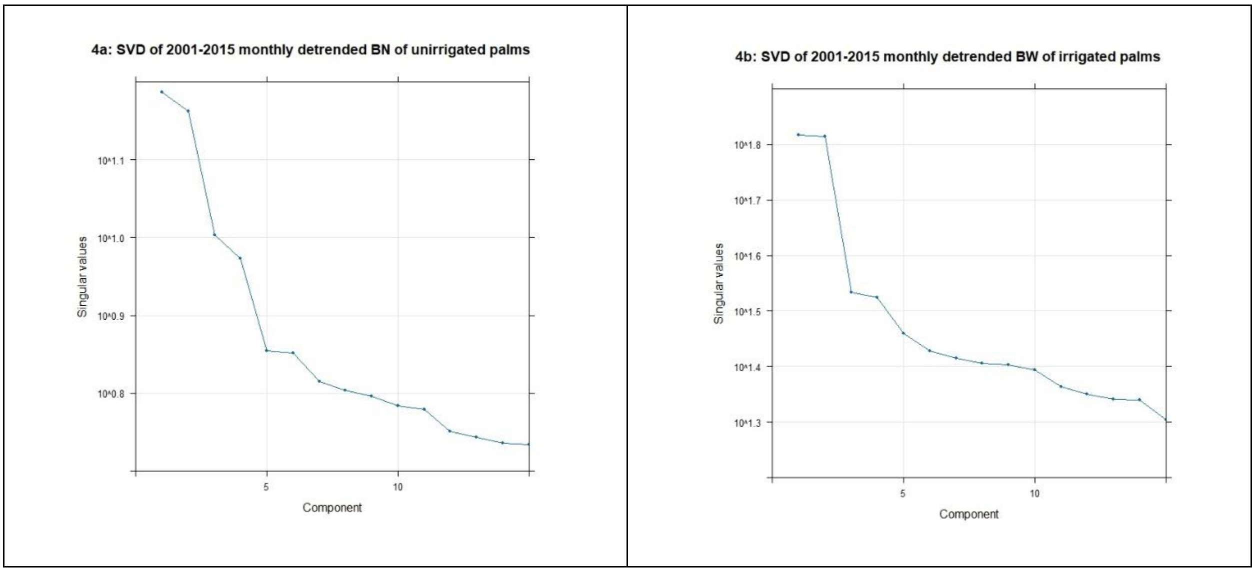

Figure 7 Screen plots of first 15 SVD components of detrended of BN_{nirr} (4a) and BW_{irr} (4b).

not all the periodicities are statistically significant, in which event they are considered residual variance or noise. The Rssa package provides for visualisation of the periodicities by graphing tapered power spectra and their frequences. We compared the output with that produced by the multitaper method (MTM), aided by harmonic F tests for significance, to decide which periodicities are relevant. For harmonic analysis, MTM is considered superior to traditional period-grams and tapered spectral analyses by better balancing bias reduction and variance control. Figure 9 is the power spectrum plot by MTM while Figure 10 gives the F tests of the spectral peaks. The origins of the key peaks and troughs are discussed below. With the isolation of the trend component(s), discovery of periodic or cyclical components and bulking the remaining variance, it is possible to reconstruct the time series. The goodness of reconstruction will indicate the quality of forecasting the time series, but forecasting is not in the ambit of this paper.

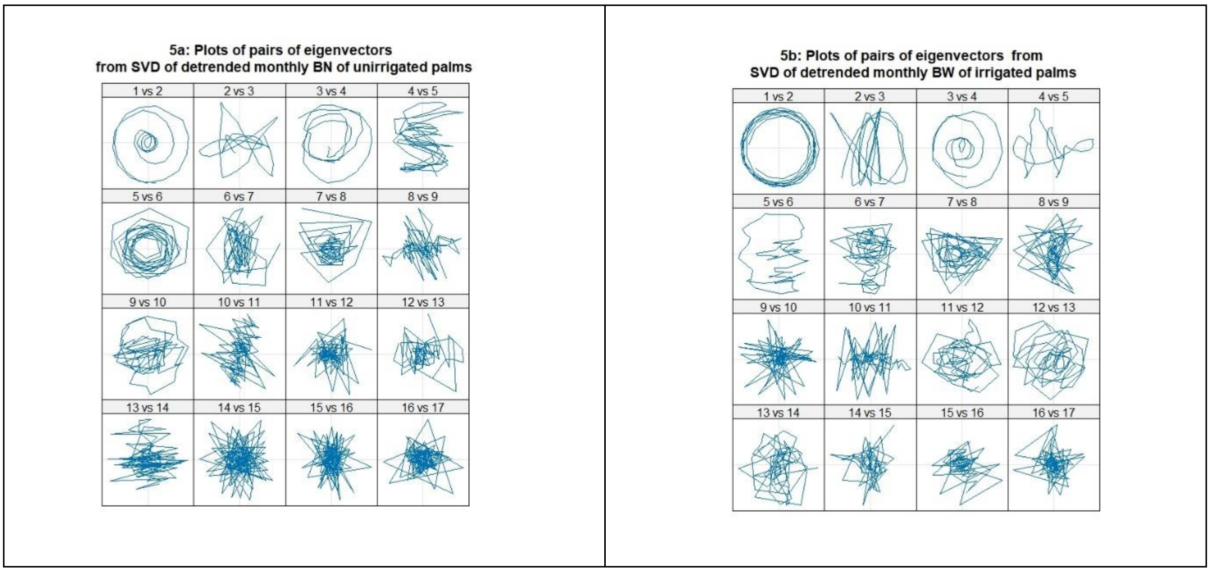

Figure 8 Plots of pairs of eigenvectors of detrended BN_{nirr} (5a) and BW_{irr} (5b).

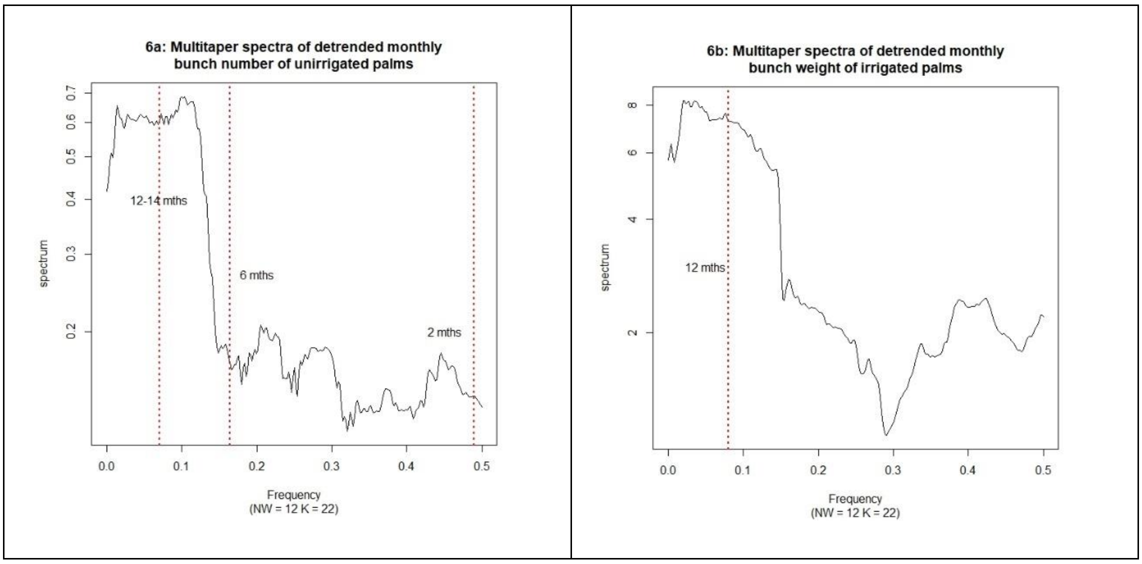

Figure 9 Multitaper spectral plots of detrended of BN_{nirr} (6a) and BW_{irr} (6b).

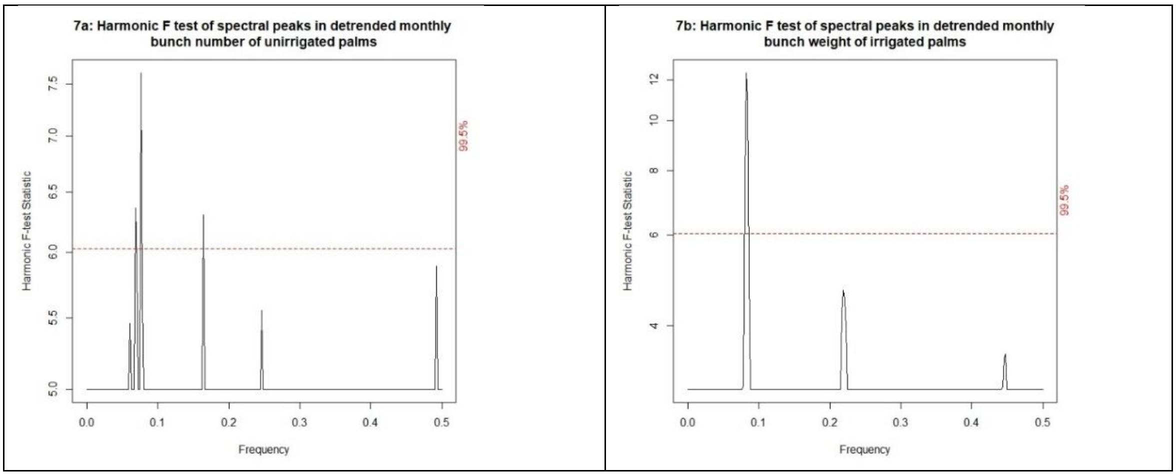

Figure 10 Harmonic F test of MTM spectral peaks of detrended BNnirr (7a) and BW_{irr} (7b). Red dashed line is 99.5% confidence.

Figure 11 shows the reconstructions of BN, BW and FFB time series from 2001–2015 with/without irrigation. The following observations obtain in both irrigated and unirrigated palms BW increases with age while BN declines, these well known in oil palms. Not surprisingly, BN_{irr} was higher than BN_{nirr} at initial bearing but the gap narrowed from about the 4th year of bearing although never quite merging. On the other hand, the gap between the trend lines for BW_{irr} and BW_{nirr} started small at about 2 kg and merged at about the 10th year of bearing at ~22 kg (see also Figure 2). FFB of both irrigated and unirrigated palms declined slightly in the final months but the data are inadequate to support any contention of an age-related decline. Besides the major trend in BW above, a minor, but generally increasing with time, damping was seen for BW in both irrigated and unirrigated palms. The damping declines to the 8th/9th year of bearing and then increases. The gross effect is that the bunches started small, then enlarged rapidly before tapering off from the 8th/9th year of bearing. This plateau occurred sooner if the hitherto increase was faster, as in good growing conditions with irrigation. BW at this age (10–12 years from planting) is about 19–21 kg. The slowdown in BN also contributed to the plateauing FFB. Oscillating around the trend, are the annual cycles for BN and BW, and, hence also for FFB. ‘Annual’ is an approximate term as the oscillation durations were from 10–14 months. For BN, the periodicity was more obvious in the young palms, the amplitude (±1) reducing after about the 5th year of bearing. The amplitude was lower in the irrigated palms (±0.5) becoming negligible after about the 9th year of bearing. For $BN_{irr,}$ in the first five years, the peaks were in May/June and the troughs in Nov/Dec shifting, with reducing amplitude, to Oct–Dec and Apr/May, respectively, over the next four years before tapering off. On the other hand, except in the first year, the peaks and troughs in BN_{nirr} were in the same respective months every year. Biologically, we believe the BN annual cycle is a response the annual rainfall cycle with good rains in the 2nd and 3rd quarters and a dry period from Dec–Mar. This prompts the alternating female and male inflorescence production, and the peaks and troughs in BN six months later. The better developed roots of the older palms would provide more access to deeper water, the better to buffers against the vagaries in rainfall and topsoil moisture, hence the diminishing annual cycle with age. The net effect of the annual cycles for BN and BW, particularly for the former, is reflected in similar cycles for FFB. Unlike BN, BW had annual cycles throughout the trial in both the irrigated and unirrigated palms-larger around Jul-Sep and smaller in Dec–Mar. In the irrigated palms the size difference was a regular ±1.5 kg throughout while in the unirrigated palms it was <0.5kg in the initial small bunches to about ±2 kg in the 6–8th year bunch before declining. Of course, as BW increases with age, the monthly fluctuations within a year are more noticeable in young palms. Field observations suggest that the female/ male cycles affecting BN mentioned above, driven by the seasonal rainfall, affects weevil numbers and pollination efficiency and, hence, BW six months later. Besides fewer male inflorescences (weevil breeding sites), weevil activity could also have been lower in the wet months. Poorly pollinated-bunches weigh less.

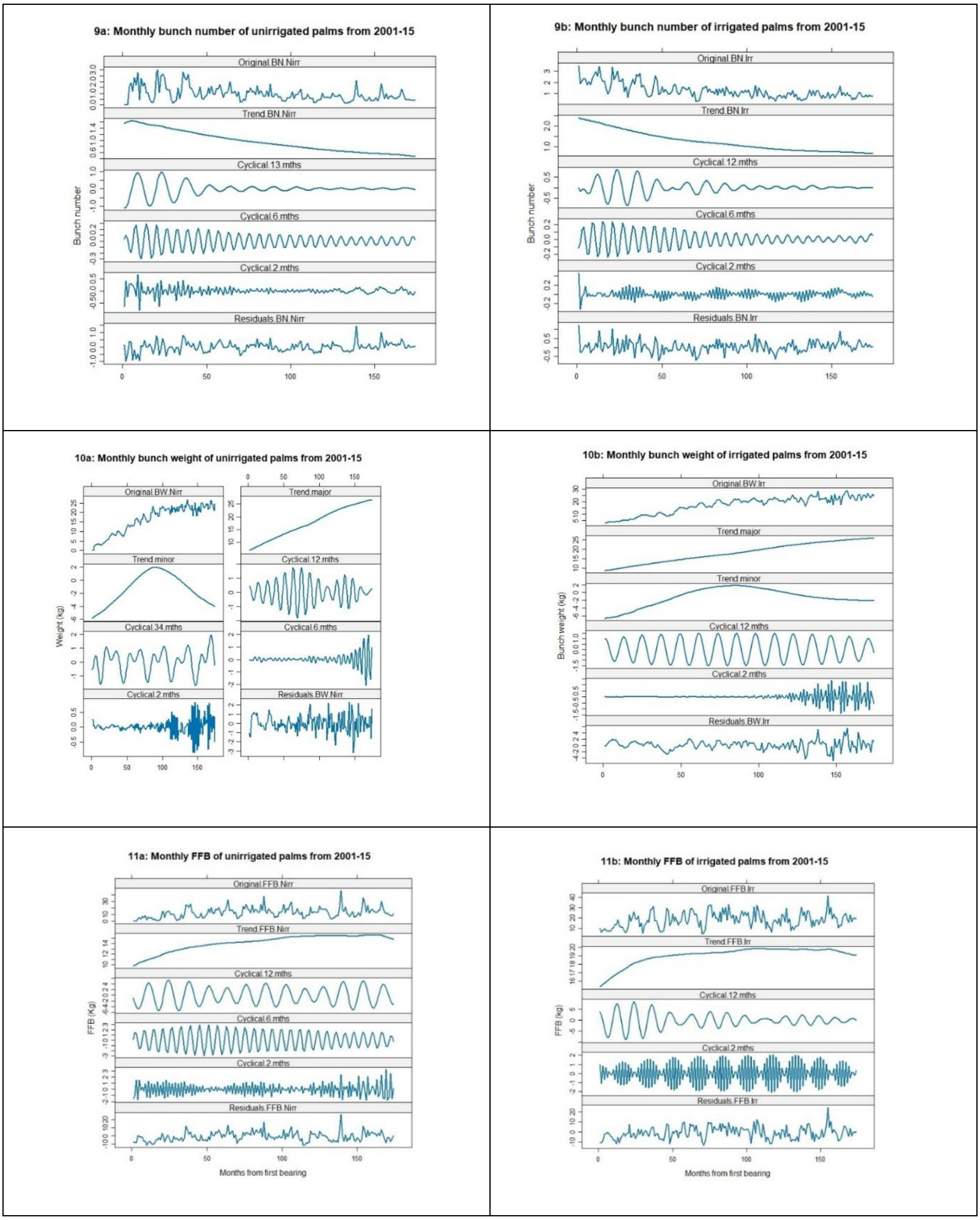

Figure 11 Reconstructed series 2001–2015: monthly BN (top), BW (middle) and FFB (bottom) for unirrigated (L) and irrigated (R) palms.

A semi-annual cycle was detected for BN with peaks in Mar/Apr and Sep/Oct followed by troughs three months later (Figure 12). We suspect that this arose from abortion of developing bunches after a bout of high production. This cycle also decreases with age. While plausible, we did not test whether this was due to more carbohydrate reserves in the older palms. An inexplicable 6-months cycle was also seen in the BW of unirrigated palms with peaks in Dec–Feb and Jun–Aug in the final few years, particularly the last two. The synchrony of this cycle with that of BN resulted in a 6-months cycle in FFB for the unirrigated palms. This cycle was not detected in BW_{irr} and, hence, nor in FFB_{irr}. Interestingly, a bimonthly cycle, with peaks in one month and troughs the next, was seen for BN, significant at 99.5%, particularly in the early unirrigated palms, and at 95% confidence for the irrigated throughout the trial. We believe this is due to imprecise harvesting, the under-ripe bunches boosting a month's, followed by a dearth in the next. A similar cycle was detected for BW in the older palms, irrigated or not. This is believed to stem from the artificial bimonthly BN cycle; - BW low in a month without bunch, then high with bunch(es). The oscillation was more pronounced in the older palms with only few large bunches to be harvested. Hence the bimonthly FFB fluctuation can be amplified/diminished by the vagaries of BN and BW; high when both are high, low when both are low and 'average' when one is high and the other low (Figure 13). Lastly, there was a consistent highly significant 34-month cycle in BW of unirrigated palms (Figure 14). We think this arose from the alternative exhaustion and replenishment of carbohydrate reserves every three years. No such cycle occurred in the irrigated palms.

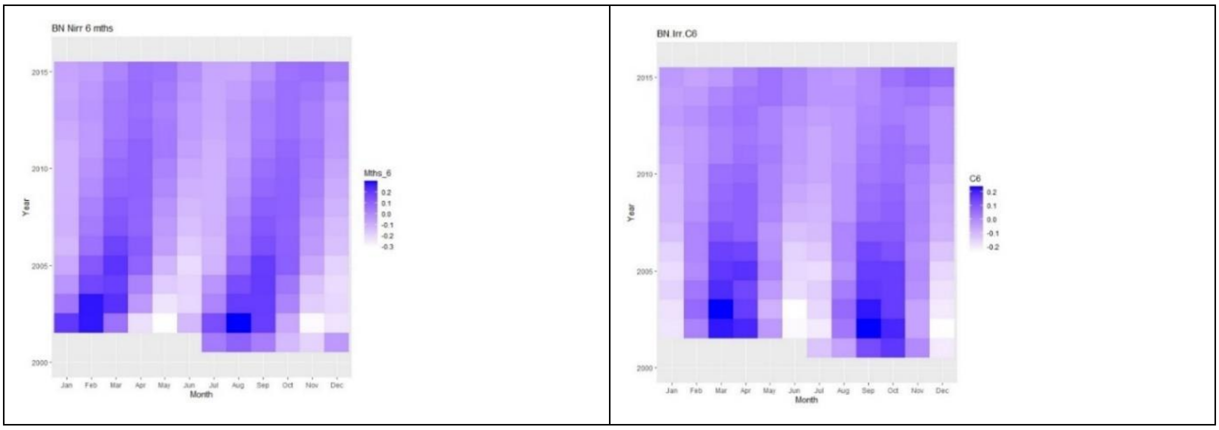

Figure 12 Semi-annual cycles in BN in unirrigated (L) and irrigated (R) palms.

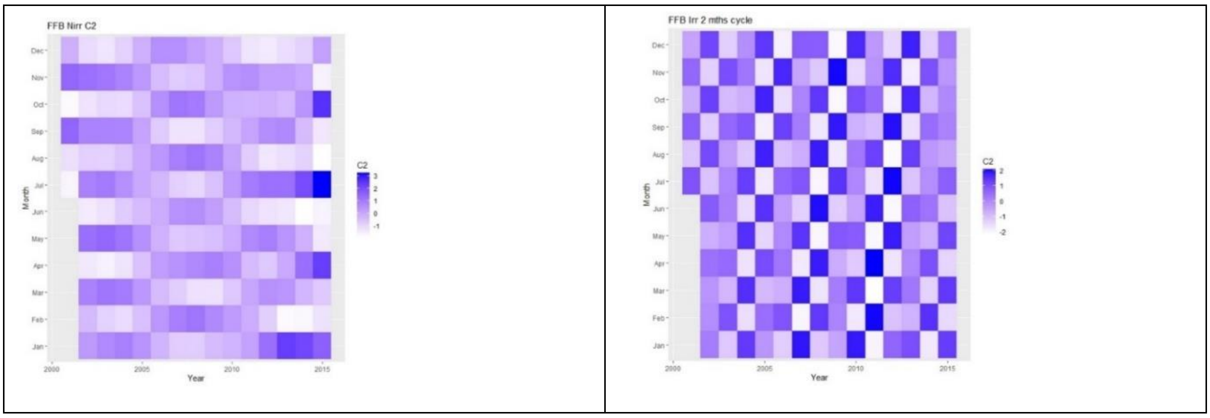

Figure 13 Bimonthly cycles in FFB production in unirrigated (L) and irrigated (R) palms.

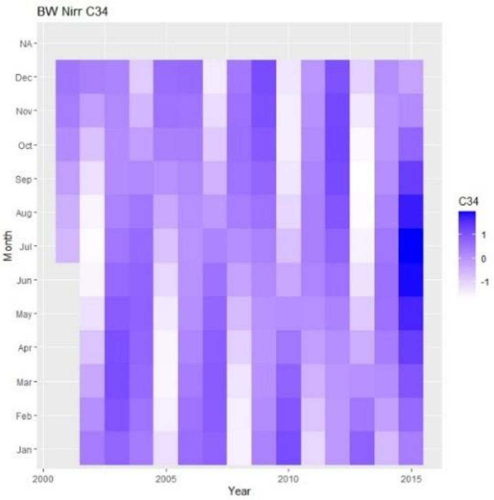

Figure 14 An approximate triennial cycle in BW of unirrigated palms.

CONCLUSIONS

The main picture of oil palm yield is the trend of fewer BN and increasing BW with age. As the latter outpaces the former, FFB rises. Age accounted for 99% of the variance in BW and 90% and 80% for BN in irrigated and unirrigated palms, respectively. Irrigation gave +38% crop, from +34% BN which averaged +5% larger. While the differences in BN prevailed throughout, BW of irrigated and unirrigated palms converged from about the 7^{th} year of bearing.

The seasonal rains triggered an annual sex cycle of female and male inflorescences, hence high and low BN about six months later. As the palms aged, their more developed roots better buffered them against the vagaries of rainfall and surface soil moisture, and dampened the yield fluctuations, especially for BN. The sex cycle and rain-reduced weevil activity resulted in BW oscillation while harvesting underripe bunches was detected as a bimonthly cycle in BN and, hence, FFB.

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IJOP publishes research papers in the fields of soil and crop fertilizer application, seedling preparation, cover crop management, leaf pruning, weed control, control of pest and diseases, insect pollinators management, water management, intercropping, cattle oil palm integration, environmental studies, harvesting technology, IT remote sensing GPS application, mechanization, sustainability standards, policy studies, social and economic studies, smallholders empowerment, palm oil mill improvement, biomass utilization, carbon footprint, water footprint, market studies, refinery, food and nutrition technology (oleofood, food safety, pharmaceutical and nutraceutical) and also management of soil preparation, inorganic and organic safety, oleochemicals, downstream industry development, supply chain, and market studies.

The published articles can be in the form of research articles, review paper or short communications which have not been published previously in other journals (except in the form of an abstract or academic thesis/dissertation or presented in seminar/conference).

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Research article

A research article is an original full length research paper which should not exceed 5000 words in length (including table and figures in good resolution). Research article should be prepared according to the following order: title, authors name and affiliations, abstract, keywords, introduction, materials and method, result and discussion, conclusion, acknowledgement (optional), and references.

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A review paper is an invited article up to 5000 words (including table and figures in good resolution). Review paper summarizes the current state of knowledge of the topic supported by up-to-date and reliable references. It creates an understanding of the topic for the reader by discussing the findings presented in recent research papers. A review paper synthesizes the results from several primary literature papers to produce a coherent argument about a topic or focused description of a field.

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A short communication is a condensed version of research article, written without chapters, up to 3500 words (including table and figures in good resolution). It consists of title, authors name and affiliations, abstract, keywords, main content, and references. The main content of the article should represent introduction, materials and method, result and discussion, and conclusion, prepared without headings. A short communication should con-tribute an important novelty for science, technology, or application.

The authors are fully responsible for accuracy of the content. Any correspondence regarding the manuscript will be addressed to the correspondent author who is clearly stated including his/her email address, telephone and fax number (including area code), and the complete mailing address. The correspondent author will handle correspondence with editor during reviewing process. The author are required to suggest two potential reviewer names including their email address.

Preparation of the manuscript

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c All table and figures should be preparedin good resolution and separate pages.
d The manuscript has not been published in any proceeding of scientific meeting or conference.
e When animal/human subject is involved in the invivo study, ethical clearance should be included in the manuscript by stating the number of ethical approval obtained from ethic committee.
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a The title of the article should be brief and informative (max. 10 words) in Arial font 16 and 1.15 spaced
b Each word of the title is initiated with capital letter, except for the species name of organisms.
c The institution where authors are affiliated should be completely written (institution name).
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Abstract

a Abstract written in one paragraph in English and 250 to 300 words.
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Keywords

The keywords consist of no more than 5 important words not found in the title, representing the content of the article and can be used as inter-net searching words and arranged in alphabetical order.

Content, Tables and Figures

Content includes introduction, materials and methods; result and discussion, conclusion, acknowledgement and references.

Example:

Figure 6 Experiment on incubation time of recombinant manCK7 for palm kernel meal treatment: a. at 1 hour until 5 hour, and b. 4 hour until 16 hour. Blanko = PKM treated with buffer phosphate pH 7, enzyme = PKM treated with recombinant manCK7.

Introduction

The introduction states background of the research, including its novelties, supported mainly by the relevant references and ended with the objectives of the research.

Materials and Methods

a The materials used should include manufacture and source. Specific instruments and equipment should be described clearly.

b The methods used in the study should be explained in detail to allow the work to be reproduced. Reference should be cited if the method had been published.

c Any modified procedures of the cited methodology should be explained clearly indicatingwhich parts modifications had been made.

d Experimental design being used includes sampling technique and statistical analysis should be explained in detail.

Results and Discussion

a Results of the study should be presented as the starting point of discussion.

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c The title of tables and figures should be numbered consecutively according to their appearance in the text.

d Statistical data in figures and tables must include standard deviation (SD) or standard error of mean (SEM) or other statistical requirements.

Conclusion

Conclusion is drawn based on the objectives of the research.

Acknowledgement (if necessary)

Acknowledgement contains the institution name of funding body/grants/sponsors or institution which provides facilities for the research project, or persons who assisted in technical work and manuscript preparation.

References

References are arranged accord-ing to Council of Science Editors (CSE) Style: Harvard system or name year system. Please further refer to https://writing.wisc.edu/Handbook/DocCSE_NameYear.html
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Examples:
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To save space, CSE suggests that writers abbreviate the titles of journals in according to the ISO 4 standard, which you can read about at ISSN. You can also search ISSN's List of Title Word Abbreviations.

Pahan I, Gumbira-Sa'id E,Tambunan M. 2011. The future of palm oil industrial cluster of Riau region Indonesia. Eur J Soc Sci. 24(3):421-431.

Purnamasari MI, Prihatna C, Gunawan AW, Suwanto A. 2012. Isolasi dan identifikasi secara molekuler *Ganoderma* spp. yang berasosiasi dengan penyakit busuk pangkal batang di kelapa sawit. J Fitopatol Indones. 8(1):9-15. DOI: 10.14692/jfi.8.1.9.

Van Duijn G. 2013. Traceability of the palm oil supply chain. Lipid Technol. 25(1):15-18. DOI: 10.1002/lite.201300251.

Book

References for books follow the order Author(s). Year.Title. Edition. Place of publication (Country Code): publisher.

Allen C, Prior P, Hayward AC. 2005. Bacterial wilt: the disease and the *Ralstonia solanacearum* species complex. St. Paul (US): APS Press.

Book chapter

References for chapters or other parts of a book follow the order Author(s). Year. Chapter title. In: Editor(s). Book title. Place of publication: publisher. Page numbers for that chapter.

Allen C. 2007. Bacteria, bioterrorism, and the geranium ladies of Guatemala. In: Cabezas AL, Reese E, Waller M, editors. Wages of empire: neoliberal policies, repression, and women’s poverty. Boulder (US): Paradigm Press. p. 169-177.

Otegui MS. 2007.Endosperm: development and molecular biology. In: Olson OA, editor. Endosperm cell walls: formation, composition, and functions. Heidelberg (DE): Springer. p. 159-178.

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