Journal of Oil Palm Research Vol. 35 (1) March 2023 p. 147-156
DOI: https://doi.org/10.21894/jopr.2022.0033

IMPROVING THE GROWTH PERFORMANCE OF OIL PALM SEEDLINGS BY MIXTURES OF ORGANIC AND CHEMICAL FERTILISERS

MOHD FAHMI KENI[1]*; NURHAFIZHOH ZAINUDDIN[1] and MOHAMED MAZMIRA MOHD MASRI[1]

ABSTRACT

The application of biofertilisers can be the best alternative to reduce the dependency on chemicals in oil palm nurseries. The impact of oil palm-based compost with a microbial-based organic fertiliser in reducing chemical use on young oil palm seedlings was investigated at the nursery stage. A total of six treatments and five controls were used in a completely randomised design (CRD). The objective of this study was to evaluate the growth of young seedlings using mixtures of chemicals with microbial-based organic fertiliser. Treatment T6 (a consortium of microbes 2 + 30% chemical) recorded the highest mean of meristem diameter (5.38 cm), and palm height (149.28 cm), and was significantly different compared to control on 10 months old seedlings. The combination of consortium microbe with 30% chemical fertiliser was optimal for the oil palm seedling growth as seen in the vegetative measurement and its nutrient contents higher compared to control. The application of biofertiliser assisted in the increase of essential nutrient content; nitrogen (N), phosphorus (P), potassium (K) and carbon (C). Our studies showed that biofertilisers performed better when chemical nutrients were added to the microbial consortium, providing a significant increase in growth performance and nutrient content.

Keywords: biofertiliser, growth performance, microorganism, nutrients content, oil palm.

Received: 20 April 2021; **Accepted:** 25 April 2022; **Published online:** 14 June 2022.

INTRODUCTION

The palm oil industry should increase oil palm yields in order to fulfil the global market demand (Iskandar *et al.*, 2018). Oil palm requires an optimum and balanced supply of nutrients to support an optimised growth and yield production (Chen, 2006; Miransari, 2013). Fertilisers are an essential component of modern agriculture because they provide plant nutrients (Adesemoye *et al*., 2009). Chemical fertilisers have been routinely applied in oil palm plantations to maintain soil fertility and also as nutrient supply to the plants (Chen, 2006; Miransari, 2013). Nutrient requirements for oil palm can vary according to the target yield, type of planting material used, palm spacing, palm age, soil type, groundcover conditions, climate and other environmental factors (Anuar *et al.*, 2015). However, the excessive usage of chemical fertilisers has caused decline in productivity and can contribute to adverse environmental impacts such as soil acidification, greenhouse gas emission and depletion of soil micro-organisms (Anuar *et al.*, 2015; Savci, 2012; Zhao *et al*., 2016). Besides that, excessive usage of fertilisers can cause negative effects on soil quality and soil microbial community structure with reduced soil organic matter (OM) and soil fertility, thus, increasing soil acidification which in turn reduces the crop yield (Li *et al.*, 2017; Qiao *et al*., 2018; Wang *et al*., 2020).

Excessive usage of synthetic fertilisers has also created a damaging impact on the global environment such as water pollution (Tang *et al.*, 2003), imbalance atmospheric gasses (Kim and Dale, 2008), groundwater pollution and soil acidification. All the factors actively contribute to reduced soil fertility for agricultural activity (Barak

[1] Malaysian Palm Oil Board,
6 Persiaran Institusi, Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia.

* *Corresponding author e-mail: fahmikeni@mpob.gov.my*

et al., 1997; Li *et al.*, 2017; Qiao *et al.*, 2018; Zhao *et al.*, 2016). The chemical fertiliser usage will also cause air and ground water pollution, resulting from eutrophication and this practice affects the roots of the crops which causes the crop to be less efficient in acquiring nutrients (Voon Kheong *et al.*, 2012; Wang *et al.*, 2009). The usage of biofertiliser in the agricultural industry is deemed as a potential solution to mitigate the harmful effects caused by chemical fertilisers (Khan *et al.*, 2012; Mohamed and Babiker, 2012). Hence, the development of organic and other microbial products in biofertilisers can therefore gradually reduce the dependence on the chemical fertiliser in oil palm plantations (Bhardwaj *et al.*, 2014; Munda *et al.*, 2015; Taryo-Adiwiganda *et al.*, 2006). Biofertiliser that is comprised of microbial inoculants or assemblages of beneficial microorganisms would benefit crop yield, and also the plant growth (Itelima *et al.*, 2018; Zainuddin *et al.*, 2019).

Biofertiliser is usually prepared by using microbial inoculant that consists of live microorganisms and commonly used for the application of seed, soil or composting areas to increase the numbers of beneficial microorganisms. This would also accelerate the microbial processes to augment the extent of the nutrient's availability in a form which can be assimilated by the plant (Khosro and Yousef, 2012; Rokhzadi *et al.*, 2008). The usage of biofertiliser accelerates the decomposition of organic residues and agricultural by-products through various processes which contribute to the healthy growth of crops (Abdul Halim, 2009). Ajeng *et al.* (2020) stated that some of the microbes contained in the biofertiliser produced by local Malaysian manufacturers include *Bacillus cereus* JCM 2152, *Bacillus amyloliquefaciens* strain MPA 1034 and *Bacillus tequilensis* strain 10b; *Lactobacillus* spp.; *Azospirillum* spp. and *Rhizobium* spp. Meanwhile, some biofertiliser products consist of a very diverse group of microbes: Actinomycetes such as *Kocuria rhizophila*, *Arthrobacter methylotrophus*, *Bacillus* spp. such as *B. pumilus*, *B. subtilis* (subspecies spizizenii), *B. vallismortis*, *B. thuringiensis*, *B. mycoides*, *B. mucilaginosus*, *Brevibacillus reuszeri*, *Paenibacillus polymax*, *Paenibacillus azoreducens* and *Azospirillum brasilense.* Additionally, fungi such as *Aspergillus niger* and *Aspergillus awamori*, and yeast such as *Saccharomyces cerevisiae* are also used as inoculants.

Biofertilisers are the most important component of integrated nutrient management and play an important role in the sustainability of soil and yield of chickpea (*Cicer arietinum* L.). It is eco-friendly and cost-effective for farmers (Rokhzadi *et al.*, 2008). The roles of beneficial soil microorganisms in the sustainable development of agriculture could accelerate and improve plant growth as well as protect plants from pests and diseases (Lee and Pankhurst, 1992; Wani *et al.*, 1995). Khosro and Yousef (2012) reported that organisms that are commonly used as components of biofertilisers are mainly nitrogen fixers (N-fixer), potassium solubilisers (K-solubiliser) and phosphorus solubiliser (P-solubiliser), or with the combination of fungi. Most of the bacteria included in the biofertiliser formulation have close relationships with plant roots. Rhizobium has symbiotic interaction with legume roots, and Rhizobacteria commonly inhabits the root surface or in rhizosphere soil. The phospho-microorganisms, mainly bacteria and fungi make insoluble phosphorus available to the plants. Several soil bacteria and several species of fungi possess the ability to convert insoluble phosphates in soil into soluble forms by secreting organic acids. However, the use of biofertiliser for commercial agricultural production, especially in oil palm, is still not widely practised by most of the plantations. Therefore, the objective of this study was to evaluate the growth of young seedlings in combination with a microbial-based organic fertiliser in the pursuit of reducing chemical usage in oil palm production.

MATERIALS AND METHODS

Oil Palm Seedling

The trial was carried out in a nursery at the Malaysian Palm Oil Board (MPOB), Kluang, Johor, Malaysia. Uniform oil palm seedlings of three months old were selected and transplanted in 15 x 18 inch polybags. Commercial *Dura* x *Pisifera* (DxP) oil palm seedlings were provided by MPOB and used in these trials.

Treatments

A total of 11 different treatments, including one control treatment (blank) were tested, as shown in *Table 1*. Six treatments with two different consortia of microbes with three levels of chemical fertilisers were carried out, as shown in *Table 2*. A completely randomised design (CRD) was used in this experiment with eight replicates for each treatment.

Preparation of Inoculum and Biofertiliser Formulation

Twelve different species of microorganisms from several classes of bacteria and fungi were utilised in the production of the biofertiliser. The microbes were chosen based on their capability to promote plant growth. The consortium of microbes consisted of five microbes from prokaryotes of the group Proteobacteria; two bacteria were from the genus *Bacillus* while the other three bacteria were from the genera of *Providencia, Phyllobacterium* and

TABLE 1. TREATMENTS OF THE EXPERIMENT

Treatment code	Treatment	Rate
T1	Treatment 1	Consortium 1 + 0% chemical
T2	Treatment 2	Consortium 1 + 15% chemical
T3	Treatment 3	Consortium 1 + 30% chemical
T4	Treatment 4	Consortium 2 + 0% chemical
T5	Treatment 5	Consortium 2 + 15% chemical
T6	Treatment 6	Consortium 2 + 30% chemical
C1	Organic fertiliser	Nursery rate
C2	Control - Blank	Nil
C3	Chemical fertiliser	Nursery rate
C4	Organic Compost A	Nursery rate
C5	Organic Compost B	Nursery rate

Note: 100% chemical fertiliser rate is 280 g/seedling in nursery stage (40.00 g/seedling/application); 100% organic fertiliser rate is 200 g/seedling in nursery stage (28.57 g/seedling/application).

TABLE 2. DIFFERENT CONSORTIUM OF MICROBES

Consortium	Microbes
Consortium 1	*Tricho* 5 N, P, K Microbe
Consortium 2	*Trichoderma harzianum* N, P, K Microbe

Sphingobacterium. Fungi consisted of three species of *Trichoderma* and one species each of *Antrodia, Pichia, Pycnoporus* and *Phanerochaete*. The microbes are capable to promote the growth of oil palm and are protected under the Malaysian Patent No: PI 2017703375.

In order to prepare the microbial consortium formulation for fungi, a malt extract broth was prepared by dissolving 19.0 g of malt extract broth powder in 400 mL of distilled water. For bacteria, 400 mL nutrient broth was prepared by dissolving 3.2 g of nutrient broth powder in 400 mL distilled water. The fermentation media were sterilised by autoclaving at 121°C for 20 min and allowed to cool down before inoculating with the individual microbes. After inoculation, the broths containing inoculum were incubated in an INNOVA44 incubator shaker at a speed of 170 rpm at 30°C for three days, to produce the fermented products. The different individual fermented microbes were pooled together based on synergistic behaviour. This microbial preparation protocol followed the optimisation method previously reported by Zainuddin *et al.* (2019).

Application of Fertiliser

The fertiliser application followed the protocol from Rankine and Fairhurst (1999) with some modifications. The commercial chemical fertiliser with a ratio of 12:12:17:2 (N: P: K: Mg), and commercial organic fertiliser, organic compost A and organic compost B were used in this study. Three-month-old oil palm seedling were treated with 11 treatments during seven months intervals. The application of fertilisers was conducted every month and their performances were monitored within seven months. The application rates for the fertilisation are as shown in *Table 1*.

Harvesting, Data Recording and Destructive Sampling

Vegetative measurements of the seedlings were recorded monthly from three to seven months after treatment (MAT). Different growth parameters such as the height, meristem diameter and dry weight of the palm were recorded during each harvest. The dried leaflets were analysed for foliar nutrients analysis. Parameters for data recording followed that of Zainuddin *et al.* (2019) with some modifications.

Leaf Analysis

Total nitrogen (TN) and total carbon (TC) analyses were carried out using PRIMACS^{SNC} (Skalar, Netherlands). Analyses of phosphorus, potassium, micronutrients and trace elements were carried out using ElanDRCe ICP-MS (Perkin Elmer, USA). For ICP-MS analysis, leaf samples were acid digested using Microwave Oven (Memmert, Germany) according to the US EPA test method 3050B (US EPA, 1996). The digested samples were filtered using filter paper and diluted with MilliQ water before analysis. Primac^{SNC} was used for the analysis of carbon and nitrogen content in oil palm leaflets. Initially, 50 mg of dried leaf samples were weighed into each crucible. The samples were then subjected to TC and TN analyses with Primac^{SNC}.

Statistical Analysis

The analyses were carried out using IBM SPSS 22.0 software. Analysis of variance (ANOVA), at $p<0.05$ was used to determine the significant difference between the treatments. The mean for each treatment for the respective analysis was separated statistically using Tukey Pairwise comparison to test the differences among mean values of every treatment.

RESULTS AND DISCUSSION

The combination of beneficial microbes with chemical fertilisers has received a considerable amount of attention in the last decades as the microbes are effective in promoting plant growth. The beneficial microbes contained in the biofertiliser had improved the plant quality, helped in nutrients intake by the plants, and enhanced the populations of bacteria (Zainuddin *et al.*, 2019). In this study, the effects of fertiliser treatments on meristem diameter, dry upper mass and palm height of oil palm seedlings are presented in *Tables 3-5*. Analysis for nitrogen, phosphorous, potassium and carbon content are presented in *Tables 6-9*.

An increase of meristem diameter in oil palm seedlings for all the treatments were observed when the seedlings reached six to 10 months old (*Table 3*). Nevertheless, the rate of increment of the meristem diameter seemed to be different between each treatment. Slight increments were observed in treatment T5 and T6 as compared to control when the seedlings reached eight to 10 months old. There was no significant difference ($p>0.05$) between all treatments and controls for oil palm seedlings aged six months. However, treatment T6 (consortium 2 + 30% chemical) showed a significant difference ($p<0.05$) as compared to C3 (chemical fertiliser) at the ages of nine and 10 months. The result recorded for treatment T6 was comparable to C3 at seven and eight months old seedlings. Compared to organic fertiliser (Organic Fertiliser and Organic Compost B), treatment T6 recorded a significant difference to control at eight months until 10 months old seedlings. Biofertilisers application has been reported to increase the trunk diameter of other trees such as grapes as compared to a non-treated tree (El-Sabagh *et al.,* 2011). In this study, treatment T6 recorded the highest mean for meristem diameter with 5.38 cm on 10 months old seedlings. The meristem diameter showed a significant difference between treatments and control after longer exposure to biofertiliser treatments. Zainuddin *et al.* (2019) reported that the oil palm seedlings treated with biofertiliser + 50% chemical fertiliser were taller than those treated with 100% chemical and standard organic at the age of eight months. The increase in meristem diameter is likely due to the microbes in the biofertiliser which are attached to the roots and hence colonised the root surfaces efficiently for the development and health of the plants (Hayat *et al*., 2010; Vacheron *et al*., 2013).

The dried upper mass for oil palm seedling had increased every month for all treatments and controls (*Table 4*). Treatment T1 and T4 (Consortium 1 and 2 + 0% chemical) recorded a two fold increase in the dry upper mass of oil palm seedlings between eight to 10 months. Means of the dry upper mass of oil palm seedlings recorded a significant difference (ANOVA, $p<0.05$) between the treatments. The results showed that there was no significant difference between all treatments and controls at the age of six months. However, treatment T6 (consortium 2 + 30% chemical) was significantly different ($p<0.05$) from chemical fertiliser (C3) at 10 months old. Mohamed and Babiker (2012) reported all inoculation treatments on faba beans in a semi-desert zone showed significant ($p\leq0.05$) increments

TABLE 3. MERISTEM DIAMETER FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Meristem diameter (cm)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	1.22 a	1.70 ab	2.44 abc	3.00 bc	3.48 abc
Consortium 1 + 15% chemical (T2)	1.21 a	1.77 ab	2.94 bcd	3.16 c	4.90 de
Consortium 1 + 30% chemical (T3)	1.20 a	1.88 ab	3.08 cd	3.33 cd	4.15 bcd
Consortium 2 + 0% chemical (T4)	1.35 a	1.75 ab	2.60 bcd	3.35 cd	3.47 abc
Consortium 2 + 15% chemical (T5)	1.27 a	1.96 b	3.28 d	3.98 de	5.08 de
Consortium 2 + 30% chemical (T6)	1.27 a	1.92 ab	3.02 cd	4.34 e	5.38 e
Organic Fertiliser (C1)	1.30 a	2.01 b	2.27 ab	2.71 abc	3.13 ab
Blank (C2)	1.19 a	1.41 a	1.76 a	2.20 a	2.77 a
Chemical (C3)	1.31 a	1.54 ab	2.55 bc	3.08 c	4.27 cd
Organic Compost A (C4)	1.02 a	1.58 ab	2.61 bcd	3.18 c	3.36 abc
Organic Compost B (C5)	1.13 a	1.52 ab	2.27 ab	2.40 ab	3.17 ab

Note: Values in each column with different letter(s) are significantly different at $p=0.05$.

in shoot dry weights between eight and 10 weeks after sowing, compared to control. Treatment T6 also showed a significant difference compared to organic fertilisers (Organic Fertiliser and Organic Compost B), between nine and 10 months. Treatment T6 recorded the highest means of dry upper mass with 31 g at the age of nine months (*Table 4*).

The increased height of the oil palm seedlings was recorded between six to 10 months (*Table 5*). The increase in dried upper mass for the oil palm seedlings was recorded every month for all treatments and controls. The seedlings' height had increased gradually from six to 10 months for all treatments. No significant differences (p>0.05) were found between all treatments and controls at the age of six to eight months. However, T6 (treatment consortium 2 + 30% chemical) was comparable to C3 (chemical fertiliser) at the age of 10 months. Treatment T6 showed a significant difference from organic fertilisers (Organic Fertiliser and Organic Compost B) between nine to 10 months. Similar findings were reported by other researchers (Azimzadeh and Azimzadeh, 2013; Namvar and Khandan, 2014; Negawer and Mahfouz, 2010). They found that inoculation with biofertilisers had increased the plants' height as compared to the non-inoculated plants. Treatment T6 recorded the highest means of palm height at 149.28 cm at 10 months. Mahfouz and Sharaf-Eldin (2007) also found that the application of biofertiliser combined with chemical fertilisers increased the vegetative growth of fennel (plant height, number of branches and herb fresh and dry weight per plant) as compared to chemical fertilisers only. Harman and Uphoff (2019) reported that some microorganisms have the opportunity to inhabit plant roots thus, becoming root symbionts which can raise crop yields by promoting the growth of both shoots and roots, enhancing, nutrient uptake, fixation and by improving plants resistance to pests and diseases.

Nitrogen content was recorded to be fluctuating between six to 10 months (*Table 6*). The nitrogen content for chemical control and Organic Compost A showed an increase between six to 10 months

TABLE 4. DRY UPPER MASS FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Dry upper mass (g)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	2.77 a	6.39 ab	12.10 ab	15.61 ab	27.70 b
Consortium 1 + 15% chemical (T2)	2.29 a	6.44 ab	20.12 bc	28.24 c	33.15 c
Consortium 1 + 30% chemical (T3)	2.47 a	8.98 ab	20.58 bc	27.05 c	33.40 c
Consortium 2 + 0% chemical (T4)	2.68 a	7.51 ab	15.40 abc	28.70 c	34.05 cd
Consortium 2 + 15% chemical (T5)	2.85 a	8.58 ab	24.87 c	30.23 c	36.71 d
Consortium 2 + 30% chemical (T6)	3.26 a	10.72 b	20.44 bc	31.00 c	36.48 d
Organic Fertiliser (C1)	2.85 a	10.38 b	14.15 abc	16.75 ab	26.67 b
Blank (C2)	2.58 a	4.98 a	7.22 a	8.78 a	18.71 a
Chemical (C3)	3.17 a	5.60 ab	17.20 abc	27.61 c	33.40 c
Organic Compost A (C4)	1.83 a	6.59 ab	17.82 abc	22.42 bc	32.26 c
Organic Compost B (C5)	2.51 a	4.80 a	12.51 ab	12.82 a	20.65 a

Note: Values in each column with different letter(s) are significantly different at p=0.05.

TABLE 5. PALMS' HEIGHT FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Palm height (cm)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	60.25 a	80.00 a	107.14 a	115.00 abc	133.66 cd
Consortium 1 + 15% chemical (T2)	56.81 a	85.12 a	112.28 a	121.00 abcd	143.20 ef
Consortium 1 + 30% chemical (T3)	59.37 a	88.62 a	116.66 a	130.83 cd	143.14 ef
Consortium 2 + 0% chemical (T4)	64.00 a	93.00 a	115.71 a	128.00 cd	143.85 ef
Consortium 2 + 15% chemical (T5)	54.87 a	88.00 a	113.14 a	131.33 cd	147.00 ef
Consortium 2 + 30% chemical (T6)	63.37 a	100.73 a	109.14 a	137.71 d	149.28 f
Organic Fertiliser (C1)	63.37 a	97.00 a	101.14 a	115.71 abc	127.00 bc
Blank (C2)	60.75 a	85.62 a	99.12 a	107.62 a	117.25 a
Chemical (C3)	62.87 a	86.42 a	100.87 a	126.57 bcd	143.42 ef
Organic Compost A (C4)	53.50 a	83.87 a	116.14 a	121.87 abcd	138.00 ab
Organic Compost B (C5)	60.00 a	84.37 a	101.62 a	108.42 ab	119.85 de

Note: Values in each column with different letter(s) are significantly different at p=0.05.

old oil palm seedlings. The findings showed that there were no significant differences between all treatments and controls between six and eight months. Treatment T6 showed significant differences compared to organic fertilisers (Organic Fertiliser, Organic Compost A and Organic Compost B) at seven and 10 months. Treatment T6 recorded the highest means of nitrogen content at 3.54% in oil palm leaves, at seven months. The beneficial effect of biofertiliser application is the improvement in nitrogen content (Shehata and El-Khawas, 2003) due to the increase of nutrient uptake by the plant (Hirel *et al.*, 2011; Sharma and Namdeo, 1999).

The phosphorus content was recorded to increase uniformly from six months until 10 months for all treatments (*Table 7*). The phosphorus content decreased at nine months but later increased by two folds at 10 months, for most of the treatments and controls due to the growth process. The results showed that treatment T6 (consortium 2 + 30% chemical) was comparable to C3 (chemical fertiliser) at all ages of oil palm seedlings. Meanwhile, treatment T6 was significantly different from organic fertiliser (Organic Compost B) between seven and 10 months. The findings of Mohammadi *et al*. (2011) showed that the application of biofertilisers (combined with the application of phosphate solubilising bacteria and *Trichoderma harzianum*) had significant effects on nutrient uptake of chickpea, with the highest leaf P content of 0.33%. This may be due to the increase in the solubility of soluble phosphorus in the plants. The treatment T3 recorded higher means of phosphorus content with 6099.72 ppm in oil palm leaves at 10 months.

The potassium content was recorded to decrease at 10 months old for all treatments and controls (*Table 8*). The potassium content was higher at 9-month-old seedlings for most of the treatments and controls. This may be due to the planting of the oil palm seedlings in polybags and the full utilisation of potassium in the soil. The finding showed that there were no significant differences between all treatments and controls at the ages of six months. However, treatment T6 (consortium 2 + 30% chemical) was comparable to C3 (chemical fertiliser) at the age of eight months. Treatment T6

TABLE 6. NITROGEN CONTENT FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Nitrogen (%)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	2.44 a	2.24 abc	2.07 a	1.74 a	1.84 ab
Consortium 1 + 15% chemical (T2)	2.60 a	2.39 bc	2.45 a	1.89 a	2.97 c
Consortium 1 + 30% chemical (T3)	2.54 a	2.76 cd	2.83 a	2.26 ab	3.04 c
Consortium 2 + 0% chemical (T4)	2.44 a	2.34 abc	2.09 a	2.43 ab	1.95 ab
Consortium 2 + 15% chemical (T5)	2.70 a	2.75 cd	2.69 a	2.28 ab	2.95 c
Consortium 2 + 30% chemical (T6)	2.71 a	3.54 e	2.92 a	2.68 c	3.05 c
Organic Fertiliser (C1)	2.93 a	2.52 bc	2.85 a	2.23 c	1.77 a
Blank (C2)	2.94 a	1.79 a	2.02 a	2.11 cd	2.17 ab
Chemical (C3)	2.36 a	3.29 de	2.88 a	2.66 d	2.99 c
Organic Compost A (C4)	2.29 a	2.49 bc	2.44 a	2.75 b	2.22 b
Organic Compost B (C5)	2.48 a	2.12 ab	1.75 a	2.24 ab	1.86 ab

Note: Values in each column with different letter(s) are significantly different at p=0.05.

TABLE 7. PHOSPHOROUS CONTENT FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Phosphorous (ppm)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	939.94 abc	1993.34 d	3302.93 d	2319.08 ab	3335.87 ab
Consortium 1 + 15% chemical (T2)	932.49 abc	1464.97 abc	2497.31 cd	2174.88 ab	5071.87 bcd
Consortium 1 + 30% chemical (T3)	1048.78 abc	1437.57 ab	2717.77 cd	1844.83 ab	6099.73 d
Consortium 2 + 0% chemical (T4)	1194.54 c	1964.11 cd	3135.40 d	2032.49 ab	4360.63 abcd
Consortium 2 + 15% chemical (T5)	1106.80 bc	1388.27 ab	2255.19 bcd	2246.18 ab	5008.72 bcd
Consortium 2 + 30% chemical (T6)	950.74 abc	2159.30 d	1991.02 bc	2157.42 ab	5496.62 cd
Organic Fertiliser (C1)	1189.14 c	1865.58 bcd	2678.35 cd	2348.97 ab	4906.56 bcd
Blank (C2)	832.22 a	1064.20 a	921.056 a	2096.15 ab	4171.86 abc
Chemical (C3)	1178.71 c	1866.86 bcd	2051.89 bc	1624.84 a	4408.47 abcd
Organic Compost A (C4)	1035.82 abc	1435.29 ab	2674.98 cd	2129.69 ab	2832.46 a
Organic Compost B (C5)	871.68 ab	1298.40 a	1214.35 ab	2493.41 b	3465.44 ab

Note: Values in each column with different letter(s) are significantly different at p=0.05.

was significantly different from organic fertiliser (Organic Compost B) at the age of seven months. Treatment T6 recorded higher means of potassium content with 2.14% in the leaves of oil palm seedlings at the age of nine months. However, the highest potassium content was found in C3 at 2.73%. This result is similar to the finding reported by Shehata and El-Khawas (2003) on sunflowers and Sharma and Namdeo (1999) on soybean. They stated that the potassium content increased significantly in response to the biofertiliser application.

Carbon content was maintained at 40.00% to 45.00% from six months until 10 months for all treatments (*Table 9*). Statistical analysis also showed that there were no significant differences between all treatments and controls at the ages of six months. However, Treatment T6 (consortium 2 + 30% chemical) was comparable to C3 (chemical fertiliser) at the age of seven months. Treatment T6 showed significant differences with organic fertiliser (Organic Compost B) at the age of eight months. Treatment T6 also recorded the highest means of carbon content, with 44.85% in the leaves of oil palm seedlings at the age of seven months. The results showed that the application of biofertilisers is one of the best management practices that could help to maintain or increase the content of OM, improve soil fertility and increase soil carbon sequestration (Bożena *et al.*, 2016).

Biofertilisers amended with chemical fertilisers are used to increase nutrient availability to the plant and can also affect the soil microbial biodiversity (Javoreková *et al*., 2015). The uptake of N from the soil as the nutrient is responsible for chlorophyll content and is also vital for the synthesis of food materials in plants which increase the vegetative measurement of the young oil palm (Fraile *et al*., 2015). It was revealed that the integration of microbial inoculants in biofertilisers was significant for plant height, diameter and yield (El-Naggar, 2010). In addition, biofertilisers alongside chemical fertilisers also improves the nutrient uptake of the seedlings and enhanced their growth in terms of height, girth size, chlorophyll content and soil nutrient status at a reduced rate to chemical fertilisers (Ajeng *et al.*, 2020).

TABLE 8. POTASSIUM CONTENT FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Potassium (%)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	0.43 a	0.45 a	1.08 abc	2.10 ab	1.47 ab
Consortium 1 + 15% chemical (T2)	0.34 a	0.48 a	1.16 abc	1.98 ab	1.32 ab
Consortium 1 + 30% chemical (T3)	0.28 a	0.50 a	2.21 d	2.08 ab	1.59 ab
Consortium 2 + 0% chemical (T4)	0.37 a	1.85 b	1.75 bcd	2.14 ab	1.57 ab
Consortium 2 + 15% chemical (T5)	0.39 a	1.79 b	1.79 bcd	2.03 ab	1.50 ab
Consortium 2 + 30% chemical (T6)	0.39 a	1.94 bc	1.81 cd	2.14 ab	1.49 ab
Fascal Embio (C1)	0.32 a	2.20 c	2.32 d	2.26 b	1.30 ab
Organic Fertiliser (C1)	0.17 a	2.18 c	0.71 a	2.22 b	1.00 a
Blank (C2)	0.29 a	2.22 c	1.64 bcd	2.73 c	1.85 b
Chemical (C3)	0.34 a	0.44 a	1.12 abc	1.86 a	1.01 a
Organic Compost A (C4)	0.37 a	0.40 a	0.90 ab	2.12 ab	1.16 a
Organic Compost B (C5)					

Note: Values in each column with different letter(s) are significantly different at *p*=0.05.

TABLE 9. CARBON CONTENT FOR SIX, SEVEN, EIGHT, NINE AND 10 MONTHS OLD OIL PALM SEEDLINGS TREATED WITH DIFFERENT TREATMENT

Treatments	Carbon (%)				
	6 months	7 months	8 months	9 months	10 months
Consortium 1 + 0% chemical (T1)	42.46 a	43.95 ab	42.79 ab	43.56 bc	39.46 a
Consortium 1 + 15% chemical (T2)	42.23 a	43.43 ab	41.77 a	42.99 b	42.99 bc
Consortium 1 + 30% chemical (T3)	42.02 a	43.36 ab	42.21 ab	43.65 bc	42.30 bc
Consortium 2 + 0% chemical (T4)	42.08 a	43.47 ab	42.87 ab	43.38 bc	43.91 bc
Consortium 2 + 15% chemical (T5)	41.17 a	43.12 a	43.34 b	43.11 b	43.37 bc
Consortium 2 + 30% chemical (T6)	41.97 a	44.85 b	43.14 b	43.12 a	41.72 ab
Organic fertiliser (C1)	38.89 a	43.93 ab	42.14 ab	43.05 a	42.24 bc
Blank (C2)	42.39 a	43.79 ab	43.00 ab	43.55 a	44.56 c
Chemical (C3)	42.00 a	43.88 ab	43.11 b	43.98 a	44.60 c
Organic Compost A (C4)	42.68 a	43.10 a	43.28 b	43.11 b	42.88 bc
Organic Compost B (C5)	42.89 a	43.72 ab	41.78 a	44.16 c	42.01 abc

Note: Values in each column with different letter(s) are significantly different at *p*=0.05.

CONCLUSION

The combined usage of chemical fertilisers with consortium microbes helped to regulate the availability of nutrients in the soil which resulted in the healthy growth of oil palm seedlings. Besides that, the consortium microbes contained in the biofertiliser had improved the plant quality, helped in nutrient intake by the plants, and enhanced the populations of phosphate-solubilising and proteolytic bacteria. Based on this study, Treatment T6 (consortium microbe 2 combines with 30% chemical fertiliser) showed higher growth performance and nutrient content in the oil palm seedlings compared to control treatments. Therefore, the use of consortium microbes as biofertiliser should be recommended as an alternative approach to reduce chemical fertiliser application, hence less harmful to the environment. Biofertilisers can now be suggested as a potential substitute for chemical fertilisers in oil palm nurseries, which could provide a positive impact on oil palm growth and sustainability.

ACKNOWLEDGEMENT

The authors would like to thank the Director-General of MPOB and the Director of Biology and Sustainability Research (BSR) Division of MPOB for supporting the project. We would also like to thank Dr. Siti Ramlah Ali (retired from MPOB in 2016) for her guidance, knowledge and support throughout the project. Last but not least, we would like to extend our appreciation to the staff of the Entomology and Integrated Pest Management (EIPM) Unit who were involved in assisting and conducting the experiments.

REFERENCES

Abdul Halim, N B (2009). *Effects of using enhanced biofertiliser containing N-fixer bacteria on patchouli growth.* B.E. Thesis, Universiti Malaysia Pahang.

Adesemoye, A O; Torbert, H A and Kloepper, J W (2009). Plant growth-promoting Rhizobacteria allow reduced application rates of chemical fertilisers. *Microb. Ecol., 58*: 921-929. DOI: 10.1007/s00248-009-9531-y.

Ajeng, A A; Abdullah, R; Malek, M A; Chew, K W; Ho, Y C; Ling, T C; Lau, B F and Show, P L (2020). The effects of biofertilisers on growth, soil fertility, and nutrients uptake of oil palm (*Elaeis guineensis*) under greenhouse conditions. *Processes, 8(12)*: 1681. DOI: 10.3390/pr8121681.

Anuar, E N; Nulit, R and Idris, A S (2015). Growth promoting effects of endophytic fungus *Phlebia* GanoEF3 on oil palm (*Elaeis guineensis*) seedlings. *Int. J. Agric. Biol., 17(1)*: 135-141. DOI: 13–1307/2015/17–1–135–141.

Azimzadeh, S M and Azimzadeh, S J (2013). Effect of nitroxin biofertiliser and nitrogen chemical fertiliser on yield and yield components of rapeseed (*Brassica napus* L.). *Int. J. Agric.Crop Sci., 6(18)*: 1284-1291. DOI: 10.2298/JAS1503361K.

Barak, P; Jobe, B O; Krueger, A R; Peterson, L A and Laird, D A (1997). Effects of long-term soil acidification due to nitrogen fertiliser inputs in Wisconsin. *Plant Soil, 197*: 61-69. DOI: 10.1023/A:1004297607070.

Bhardwaj, D; Ansari, M W; Sahoo, R K and Tuteja, N (2014). Biofertilisers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microb. Cell Factories, 13*: 66. DOI: 10.1186/1475-2859-13-66.

Bożena, D; Jacek, D; Anna, P D and Magdalena, B S (2016). The impact of a bio-fertiliser on the soil organic matter status and carbon sequestration - Results from a field-scale study. *J. Soils Sediments, 16*: 2335-2343. DOI: 10.1007/s11368-016-1430-5.

Chen, J H (2006). The combined use of chemical and organic fertiliser and or biofertiliser for crop growth and soil fertility. Paper presented at the International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertiliser Use. Land Development Department, Bangkok, Thailand. 16-20 October 2006.

El-Naggar, A H (2010). Effect of biofertiliser, organic compost and mineral fertilisers on the growth, flowering and bulbs production of *Narcissus Tazetta*, L. *J. Agric. Env. Sci. Alex. Univ. Egypt, 9(1)*: 24-52. DOI: 10.21608/alexja.2017.5788.

El-Sabagh, A S; El-Morsy, F M and Farag, A R (2011). Effect of biofertilisers as a partial substitute for nitrogen on vegetative growth, yield, fruit quality and leaf mineral content of two seedless grape Cultivars I: Vegetative growth and yield. *J. Horticultural Science and Ornamental Plants, 3(2)*: 166-175.

Fraile, G P; Menendez, E and Rivas, R (2015). Role of bacterial biofertilisers in agriculture and forestry. *AIMS Bioeng., 2(3)*: 183-205. DOI: 10.3934/BIOENG.2015.3.183.

Harman, G E and Uphof, N (2019). Symbiotic root-endophytic soil microbes improve crop productivity and provide environmental benefits. *Scientifica, 2019*: 1-25. DOI: 10.1155/2019/9106395.

Hayat, R; Ali, S; Amira, U; Khalid, R and Ahmed, I (2010). Soil beneficial bacteria and their role in plant growth promotion: A review. *Ann. of Microbiol., 60(4)*: 579-598.

Hirel, B; Tetu, T; Lea, P J and Dubois, F (2011). Improving nitrogen use efficiency in crops for sustainable agriculture. *Sustainability, 3(9)*: 1452-1485.

Iskandar, M J; Azizah, B; Farah, H A and Rizafizah, O (2018). Palm oil industry in Southeast Asia and the effluent treatment technology - A review. *Environ. Technol. and Innov., 9*: 169-185.

Itelima, J U; Bang, W J; Onyimba, I A; Sila, M D and Egbere, O J (2018). Bio-fertiliser as key player in enhancing soil fertility and crop productivity: A Review. *Direct Res. J. Agric. and Food Sci., 6*: 73-83.

Javoreková, S; Maková, J; Medo, J and Kovácsová, S (2015). Effect of bio-fertilisers application on microbial diversity and physiological profiling of microorganisms in arable soil. *Eurasian J. Soil Sci., 4*: 54-61.

Khan, Z; Tiyagi, S A; Mahmood, I and Rizvi, R (2012). Effects of N fertilisation, organic matter and biofertilisers on the growth and yield of chilli in relation to management of plant-parasitic nematodes. *Turk. J. Bot., 36*: 73-81.

Khosro, M and Yousef, S (2012). Bacterial biofertilisers for sustainable crop production: A Review. *J. Agric. Biol. Sci., 7(5)*: 307-316.

Kim, S and Dale, B E (2008). Effects of nitrogen fertiliser application on greenhouse gas emissions and economics of corn production. *Environ. Sci. Technol., 42*: 6028-6033.

Lee, K E and Pankhurst, C E (1992). Soil organisms and sustainable productivity. *Aust. J. Soil Res., 30*: 855-892. DOI: 10.1071/SR9920855.

Li, X G; Jia, B; Lv, J; Ma, Q; Kuzyakov, Y and Li, F (2017). Nitrogen fertilization decreases the decomposition of soil organic matter and plant residues in planted soils. *Soil Biol. Biochem., 112*: 47-55.

Mahfouz, S A and Sharaf-Eldin, M A (2007). Effect of mineral *vs*. biofertiliser on growth, yield and essential oil content of fennel *(Foeniculum vulgare* Mill.). *Int. Agrophys. 21*: 361-366.

Miransari, M (2013). Soil microbes and the availability of soil nutrients. *Acta Physiol. Plant, 35(11)*: 3075-3984.

Mohamed, S S E and Babiker, H M (2012). Effects of *Rhizobium* inoculation and urea fertilization on faba bean (*Vicia faba* L.) production in a semi-desert zone. *Adv. Environ. Biol., 6*: 824-830.

Mohammadi, K; Ghalavand, A; Aghaalikhani, M; Heidari, G R and Sohrabi, Y (2011). Introducing the sustainable soil fertility system for chickpea (*Cicer arietinum* L.). *Afr. J. Biotechnol., 10(32)*: 6011-6020.

Munda, S; Shivakumar, B G; Gangaiah, B; Manjaiah, K M; Rana, D S; Layek, J and Koneru, L (2015). Influence of direct and residual phosphorus fertilisation on growth and yield of potato in a soybean-potato cropping system. *Aust. J. Crop Sci., 9(3)*: 191-202.

Namvar, A and Khandan, T (2014). Biopriming and mineral fertilisers effects on agronomical performance of rapeseed (*Brassica napus* L.). *Ekologija, 60(3)*: 54-63.

Negawer, E A and Mahfouz, S A (2010). Response of canola (*Brassica napus* L.) to biofertilisers under Egyptian conditions in newly reclaimed soil. *Int. J. Agric. Sci.*, 2(1): 12-17.

Qiao, C; Xu, B; Han, Y; Wang, J; Wang, X; Liu, L; Liu, W; Wang, S; Tan, H; Liu, Y and Zhao, X (2018). Synthetic nitrogen fertilisers alter the soil chemistry, production and quality of tea. A meta-analysis. *Agron. Sustain. Dev., 38(1)*: 1-10.

Rankine, I R and Fairhurst, T H (1999). Pocket Guide: Oil Palm Series, Volume 4: Nursery. IPNI Southeast Asia Program (IPNI SEAP). Penang. 82 pp.

Rokhzadi, A; Asgharzadeh, A; Darvish, F; Nour-Mohammadi, G and Majidi, E (2008). Influence of plant growth-promoting rhizobacteria on dry matter accumulation and yield of chickpea (*Cicer arietinum* L.) under field condition. *Am-Euras. J. Agric. Environ. Sci., 3(2)*: 253-257.

Savci, S (2012). An agricultural pollutant: Chemical fertiliser. *Int. J. Environ. Sci. Dev., 3(1)*: 11-14.

Shehata, M M and El-Khawas, S A (2003). Effect of two biofertilisers on growth parameters, yield characters, nitrogenous components, nucleic acids content, minerals, oil content, protein profiles and DNA banding pattern of sunflower (*Helianthus annus* L. cv. Vedock) yield. *Pak. J. Biol. Sci., 6(14)*: 1257-1268.

Sharma, K N and Namdeo, K N (1999). Effect of biofertiliser and phosphorous on NPK contents, uptake and grain quality of soybean (*Glycine max* L. Merrill) and nutrient status of soil. *Crop Res. (Hisar) 17*: 164-169.

Tang, D; Kester, D R; Ni, I; Qi, Y and Kawamura, H (2003). *In situ* and satellite observations of a harmful algal bloom and water condition at the Pearl River estuary in late autumn 1998. *Harmful Algae, 2:* 89-99.

Taryo-Adiwiganda, Y; Balaman, T and Berani, P (2006). Effect of bio fertiliser on mature oil palm in North Sumatra and Riau. *Indones. J. Agric. Sci., 7(1)*: 20-26.

US EPA (1996) *Method 3050B: Acid Digestion of Sediments, Sludges, and Soils*. Second Revision. Washington, DC.

Vacheron, J; Desbrosses, G; Bouffaud, M L; Touraine, B; Loccoz, Y M; Muller, D; Legendre, L;Dye, F W and Prigent-Combaret, C (2013). Plant growth promoting rhizobacteria and root system functioning. *Front. in Plant Sci., 4:* 356.

Voon Kheong, L; Rahman, Z A; Musa, M H and Hussein, A (2012). Effects of severing oil palm roots on leaf nutrient levels and P uptake. *J. Oil Palm Res., 24:* 1343-1348.

Wang, J; Li, R; Zhang, H; Wei, G and Li, Z (2020). Beneficial bacteria activate nutrients and promote wheat growth under conditions of reduced fertiliser application. *BMC Microbiol., 20(38*): 1-12.

Wang, B; Lai, T; Huang, Q W; Yang, X M and Shen, Q R (2009). Effect of N fertilisers on root growth and endogenous hormones in strawberry. *Pedosphere, 19*: 86-95.

Wani, S P; Rego, T G; Rajeshwari, S and Lee, K K (1995). Effect of legume-based cropping systems on nitrogen mineralization potential of Vertisol. *Plant Soil., 175(2)*: 265-274.

Zainuddin, N; Keni, M F and Ibrahim, S A S (2019). Effect of biofertiliser containing different percentage rates of chemical fertiliser on oil palm seedlings. *J. Oil Palm Res., 31(4)*: 582-591.

Zhao, J; Ni, T; Li, J;Lu, Q; Fang, Z; Huang, Q; Zhang, R; Li, R; Shen, B and Shen, Q (2016). Effect of organic-inorganic compound fertiliser with reduced chemical fertiliser application on crop yields, soil biologcalactivity and bacterial community structure in a rice-wheat cropping system. *Appl. Soil Ecol., 99*: 1-12.