International Journal of Biotechnology and Microbiology
Online ISSN: 2664-7680; Print ISSN: 2664-7672
Received: 03-11-2018; Accepted: 05-12-2018; Published: 05-01-2019
www.biotechnologyjournals.com
Volume 1; Issue 1; 2019; Page No. 11-16

Direct palm oil mill effluent (POME) application diminishes nodulation and other physiological developments in *Arachis hypogea,* a leguminous plant

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Abstract
Nodulation is a key biological process mediated through a symbiotic partnership between some resident soil bacteria e.g. Rhizobium and leguminous plants leading to the formation of nodules on roots of infected plants. Nitrogen fixation take place within specialized compartments in the nodules called heterocysts. Nitrogen is critical to plant metabolism and crop production. In the present study, *Arachis hypogea* grown in mesocosms were treated separately with different concentrations (25, 50, 75, and 100%) of aerobically and anaerobically digested POME. The plants were sampled fortnightly and checked for degree of nodulation and other growth characteristics. Results show that low (25%) concentrated POME treatments promoted beneficial responses than those amended with higher (50, 75 and 100%) concentrations. For instance, after 5 weeks, pH increased from 5.4±0.14 in the control treatment to 6.2±0.07 (aerobically digested) and 5.9±0.07 (anaerobically digested) respectively. At higher POME concentrations, there was no significant change in pH compared to the control. Nodulation was also highest in mesocosms treated with 25% POME. The number of nodules found in the control was 28.5±0.5 but in the aerobically and anaerobically digested treatments, 37.5±0.5 and 23.5±0.5 nodules were produced respectively. There was zero nodulation at 75 and 100% amendments with anaerobic POME digests. The same trend was observed with other growth features of the plant. In mesocosms treated with 100% POME, there was a significant reduction ($p<0.05$) leaf length and width, stem length and root length. The application of highly concentrated POME negatively affected all the soil and plant indices monitored. Data obtained from the present study indicate that application of low concentrated (25%) POME residues could be useful as mordant, conditioner and fertilizer since microbial activity around the rhizosphere was promoted as indicated by the proliferation of nodulation and other plant features.

Keywords: *Arachis hypogea*, mesocosms, POME, nodulation, mordant, condition

Introduction

Many industrial activities produce wastes which interfere with normal ecological functioning and thereby constitute serious threats to both human and animal health (Olorunfemi *et al*. 2008) [13]. Pollution with wastewaters is one of the major global challenges confronting our environment. Presently, treatment had mainly been done using conventional treatment systems such as activated sludge, biological nutrient removal and chemical methods. However, some of these technologies are expensive, dependent on skilled personnel and sometimes impossible to carry out with large volume of contaminated materials (Dhanya and Jaya, 2013) [6].

The global production of palm oil is growing at a very fast rate and pollution caused by the waste effluent has become a serious problem. Palm oil processing is carried out using large quantities of water in mills where oil is extracted from palm fruits. During the extraction process, about 50% of the water results in effluents called Palm Oil Mill Effluents (POME). POME has high organic load and contain substantial amounts of plant materials which could be used as low cost source of plant nutrients when fermented. Raw or partially treated POME has an extremely high content of degradable organic matter, which is due in part to the presence of unrecovered palm oil (Ahmad *et al*. 2003) [2]. The toxic effect often associated with POME is due to the presence of phenols and other organic acids (Pascual *et al*., 2007) [20]. However, the polyphenolic fractions degrade with time and partially transforms into humic substances (Piotrowska *et al.* 2006) [22]. POME, if untreated, contains high amounts of fatty acids, proteins, carbohydrates and other plant materials (Ngan *et al*. 1996.) [10], which can alter critical environmental parameters such as biological oxygen demand (BOD), dissolved oxygen (DO), carbon/nitrogen (C/N) ratio and chemical oxygen demand (COD) (Okwute and Isu, 2007) [12]. POME is highly polluting and causes deterioration of inland waterways due to oxygen depletion and other related effects. Discharged POME turns the aquatic ecosystem brown, smelly and slimy (Awotoye *et al*. 2011) [3], kill fishes and other aquatic organisms and deny the human population assess to potable water (Ezemonye *et al*. 2008) [8]. Orji *et al*. (2006) [17] reported that soils where POME is freshly discharged had very scanty microbial population and diversity.

Presently little information is known on the impact of POME on nodulation and other plant physiological (leaf length, leaf width, stem length and root length) development. Nodulation is the formation of nodules on the roots of leguminous plants. The nodules are populated by groups of symbiotic bacteria which play important roles in plant nitrogen fixation. They harbor a host-specific response mechanism which ensures that every rhizobium has a defined host-plant range. Many microorganisms fix nitrogen symbiotically by partnering with a host plant. The plant provides sugars from photosynthesis which are utilized by the nitrogen fixing microorganisms for their energy supplies. In return, the microbes provide fixed nitrogen to the plant for its growth and development. Nitrogen fixing bacteria are a specialized group of prokaryotes. They include organisms such as cyanobacteria, free-living soil bacteria (i.e. *Azotobacter, Bacillus, Clostridium, Klebsiella*), bacteria that form association with plants (e.g. *Azospirillum*) and bacteria such as *Rhizobium and Bradyrhizobium* that form symbiosis with legumes (Vadakattu and Paterson, 2006) [26]. Although these organisms play important roles in the global ecology of nitrogen fixation; however, by far the most important nitrogen fixing symbiotic associations are the relationship between legumes and rhizobium. The rhizobium bacteria colonize the host plants root system and cause the roots to form nodules that protects the bacteria and provides the microaerophilic climate necessary for the process to thrive. Once encapsulated within the nodules, the bacteria begin nitrogen fixation for the benefit of the plant. Nitrogen promotes foliage development in plants and increases their photosynthetic capacity. Plants grown in nitrogen deficient soils bear striking resemblance to non-nodulated legumes. They appear chlorotic, display low nitrogen content and produces very little harvest. POME is rich in organic materials and could be useful as organic fertilizers except that they are presently underutilized due to their high phenol content. Presently, there are no effective and sustainable treatment system. This present study investigates the impact of POME on nodulation and other plant growth parameters.

2. Materials and Methods

2.1 Sample collection

2.1.1 Soil sample collection

Soil samples were collected from the agricultural farm near the Crop Science Department, University of Nigeria, Nsukka at 0-15 cm depth. They were put into sterile containers and transported to the laboratory for processing. Fresh POME samples were collected from local palm oil producers in Nsukka.

2.1.2 Collection of groundnut seeds

Groundnut seeds were purchased from Ogige market Nsukka and taxonomically identified as *(Arachis hypogea)* by Dr. E.O. Onu of the Crop Science Department, University of Nigeria, Nsukka. The seeds were planted in mesocosms and used in the described experiment.

2.2 Experimental design/Sample Preparation and Analysis

The sampled soil was passed through a 2 mm sieve, sorted to remove stones and plant materials and then thoroughly mixed to ensure homogeneity. Approximately two kilograms (2 kg) of the sampled soil was weighed and placed separately into nine plastic pots or mesocosms for the cultivation of the legume (*Arachis hypogea*). Each mesocosm contained a plant density of five. Separate batches of POME were sieved to remove excess oil and plants materials and allowed to ferment at room temperature (aerobically and anaerobically) for 20 days with continuous stirring. Germinating seeds were grown till they developed 2-3 leaves and attained a height of 4-5cm before they were watered with graded concentration (25, 50, 75 and 100%) of the fermented POME. Plants were harvested weekly and examined for effects of the POME on nodule development and other growth indices such as leaf length and width as well as stem and root length. The physicochemical properties of the agricultural soil used in the experiment as well as the fresh POME and the aerobically/anaerobically treated POME have been reported (Onwusi and Nwuche, 2017) [14].

2.3 Statistical analysis

Statistical analysis of the results obtained was done with Post Hoc Test (Tukey test) analysis of variance (ANOVA) SPSS statistical software version 23 to assess the level of significance at $P < 0.05$ and were reported as mean ± standard deviation (SD) of triplicate experiments.

3. Results and Discussion

POME has long been regarded as a waste product due to its potent phytotoxicity despite its proven richness in organic materials. However, fermented POME contains numerous breakdown minerals and nutrients which could be effective as organic fertilizers. Research have shown that partially treated (fermented) POME usually have an extremely high content of degradable organic matter which is said to be due to the presence of unrecovered palm oil and the activity of microorganisms in bio degradation of toxic substances (Ahmad *et al*. 2003) [2]. POME contains low organic load, near alkaline pH, substantial amounts of plant nutrients and represent a low-cost source of plant fertilizers when fermented (Piotrowska *et al*. 2006) [22]. In the present study, the effect of aerobically and anaerobically fermented POME on the nodulation and plant growth (leaf length, leaf width, stem length and root length) characteristics were investigated.

3.1 Impact of fermented POME on the soil rhizosphere pH

The soil changed in response to the application of aerobically and anaerobically fermented POME. The changes in pH values of the rhizosphere soil after treatment with graded concentration of the different fermented POME is set out in Table 4. The pH of the control treatment (soil) increased from 5.4±0.14 to 5.5±0.14 by the fifth week. The pH of POME treated soils increases with decrease in POME concentration. A significant decrease ($P< 0.05$) was observed between the pH of soils treated with 25% POME and those that received higher (75% and 100%) concentrations. At low POME concentrations, the 25% of aerobically digested POME brought about increase in the pH of the soil to near alkaline (6.2±0.07) state, while in the anaerobically digested POME, final pH was 5.9±0.07after 5 weeks. The lowest pH values (5.3±0.07 to 5.7±0.07) were found in soils treated with high (75 and100%) POME amendments whether aerobically or anaerobically digested. This observation is consistent with other works such as Onyia *et al*. (2001) [15] and Nwoko and Ogunyemi (2010) [11]. Under acidic conditions, the major soil nutrients principally nitrogen, potassium and phosphorus cannot effectively promote high crop yields. However, at pH approximately 5.5, low levels of these mineral elements occur in the soil. Plants flourish in soils with near neutral pH of 6.5 to 7.5. Adeniyan *et al*. (2011) [1] reported that the pH of different soils treated with organic manures improved to near alkalinity (pH 6.5) more than the soil treated with inorganic NPK fertilizer (pH 5.74). This implies that organic manure could serve in improving soil fertility. However, the report by Nwoko and Ogunyemi (2010) [11] indicated that increase in available N, P and K are due to the biodegradation and decrease in the acidic nature of untreated POME. Aerobic and anaerobically digested POME showed appreciable level of nitrogen (N), Phosphorus (P) and available Potassium (K) compared to the fresh POME. This observation might result from the mineralization of organic matter in the treated POME due to the favorable conditions presented by the fermentation process for microbial activity. However, aerobically digested POME indicated higher degradation rate than the anaerobically fermented POME. It has been reported that the major factors that influence organic N availability from wastewater are its inorganic N content (Hutchings, 1984) [9], digestion process (aerobic and anaerobic) (Serna and Pomares, 1992) [24], C: N ratio (Sims, 1990), pH and physiochemical properties (Hutchings, 1984) [9]. However, after aerobic and anaerobic digestion, there was reduction in the acidity of the POME to pH 5.0±0.2. This tendency towards alkalinity could be attributed to nitrification activities of the NH^4-N components in POME (Pascual *et al*., 2007) [20] as well proteolytic activity which releases ammonia thereby causing an increase in the pH of the medium (Parihar, 2012) [19].

Table 1: Effect of different POME concentrations on pH of the rhizosphere after weeks of treatment

POME Concentration (%)									
Week	**Control**	**Aerobically Digested POME**				**Anaerobically Digested POME**			
		25	**50**	**75**	**100**	**25**	**50**	**75**	**100**
1	5.4 ± 0.14^{Ca}	5.3 ± 0.14^{CDa}	5.2 ± 0.07^{BCDa}	5.0 ± 0.07^{ABCa}	4.8 ± 0.07^{Aa}	5.2 ± 0.07^{BCDa}	5.0 ± 0.07^{ABCa}	4.9 ± 0.07^{ABa}	4.7 ± 0.07^{Aa}
2	5.5 ± 0.14^{Fa}	5.4 ± 0.14^{EFa}	5.3 ± 0.00^{DEFab}	5.1 ± 0.07^{ABCDab}	4.9 ± 0.00^{ABab}	5.3 ± 0.07^{CDEFab}	5.2 ± 0.07^{BCDEab}	5.0 ± 0.07^{ABCa}	4.8 ± 0.07^{Aab}
3	5.5 ± 0.14^{CDa}	5.7 ± 0.14^{Dab}	5.5 ± 0.07^{CDbc}	5.3 ± 0.07^{ABCbc}	5.1 ± 0.07^{ABbc}	5.5 ± 0.07^{CDb}	5.3 ± 0.00^{BCb}	5.1 ± 0.00^{ABab}	4.9 ± 0.07^{Ab}
4	5.5 ± 0.14^{BCDa}	6.1 ± 0.07^{Eb}	5.7 ± 0.07^{Dcd}	5.5 ± 0.07^{BCDcd}	5.2 ± 0.00^{ABc}	5.8 ± 0.14^{DEc}	5.6 ± 0.07^{CDc}	5.3 ± 0.07^{ABCc}	5.1 ± 0.07^{Abc}
5	5.5 ± 0.14^{ABCa}	6.2 ± 0.07^{Eb}	5.9 ± 0.07^{DEd}	5.7 ± 0.07^{BCDd}	5.5 ± 0.07^{ABCd}	5.9 ± 0.07^{DEc}	5.7 ± 0.00^{CDc}	5.4 ± 0.07^{ABc}	5.3 ± 0.00^{Ac}

KEY: Alphabets in capital letters = Mean difference significant between various %concentration of POME treatment
Alphabets in small letters = Mean difference significant within a particular %concentration of POME treatment
NOTE: Same capital letters are not statistically different among treatments by the Turkey test ($p<0.05$) and small lower cap letters are not statistically different among weeks by the Turkey test ($p<0.05$) ± standard deviation.

Table 2: Effect of different POME concentration on the nodulation *Arachis hypogea* after weeks of treatment

POME Concentration (%)									
Week	**Control**	**Aerobically Digested POME**				**Anaerobically Digested POME**			
		25	**50**	**75**	**100**	**25**	**50**	**75**	**100**
1	8.5 ± 0.5^{Fa}	7.5 ± 0.5^{Ea}	6.5 ± 0.5^{Da}	2.5 ± 0.5^{Ba}	$0. 0\pm0.0^{Aa}$	5.5 ± 0.5^{Ca}	2.5 ± 0.5^{Ba}	0.0 ± 0.0^{Aa}	0.0 ± 0.0^{Aa}
2	9.5 ± 0.5^{Ia}	8.5 ± 0.5^{Ha}	7.5 ± 0.5^{Ga}	4.5 ± 0.5^{Ea}	2.5 ± 0.5^{Ca}	6.5 ± 0.5^{Fa}	3.5 ± 0.5^{Da}	1.0 ± 0.0^{Ba}	0.0 ± 0.0^{Aa}
3	21.5 ± 0.5^{Hb}	33.5 ± 0.5^{Ib}	16.5 ± 0.5^{Fc}	12.5 ± 0.5^{Eb}	8.5 ± 0.5^{Cb}	17.5 ± 0.5^{Gb}	9.5 ± 0.5^{Db}	3.5 ± 0.5^{Bb}	0.0 ± 0.0^{Aa}
4	27.5 ± 0.5^{Gc}	35.5 ± 0.5^{Hb}	17.5 ± 0.5^{Ec}	13.5 ± 0.5^{Db}	9.5 ± 0.5^{Bb}	21.5 ± 0.5^{Fc}	12.5 ± 0.5^{Cc}	0.0 ± 0.0^{Aa}	0.0 ± 0.0^{Aa}
5	28.5 ± 0.5^{Fc}	37.5 ± 0.5^{Gc}	18.5 ± 0.5^{Dc}	14.5 ± 0.5^{Cb}	9.5 ± 0.5^{Bb}	23.5 ± 0.5^{Ec}	14.5 ± 0.5^{Cc}	0.0 ± 0.0^{Aa}	0.0 ± 0.0^{Aa}

KEY: Alphabets in capital letters = Mean difference significant between various %concentration of POME treatment
Alphabets in small letters = Mean difference significant within a particular %concentration of POME treatment
NOTE: Same capital letters are not statistically different among treatments by the Turkey test ($p<0.05$) and small lower cap letters are not statistically different among weeks by the Turkey test ($p<0.05$) ± standard deviation.

3.2 Nodulation and other plant physiological parameters

The influence of application of aerobically and anaerobically fermented POME on root nodulation, leaf length, leaf width, stem length and root length are shown in Tables 2-6 respectively. After POME treatment, there were significant ($P<0.05$) differences in nodulation compared to the control plant. However, these changes were found to be dependent on the concentration gradient (i.e. 25, 50, 75, and 100%) as well as on the mode of digestion (aerobic and anaerobic) adopted. Results show that the 25% aerobically digested POME promoted the highest level of nodulation (37±0.5) by the 5^{th} week. In the mesocosms treated with anaerobically digested POME, the number of nodules developed after the same level of treatment (25%) was 23.5±0.5. At 100% treatment with aerobically digested POME, the nodulation process diminished to 9.5±0.5 while in the mesocosms treated with anaerobic digestate, there was zero nodulation at both 75 and 100% treatments. Nodulation is stimulated when the rhizosphere organisms called rhizobia are drawn to the host legume roots as a result of certain chemical attractants (flavonoids) released by the roots. According to Cheng and Walker, (1998) [5], the bacteria at first attaches to the epidermal cells of the root hairs and begins to proliferate. As a result of their metabolism, several compounds are released which cause the colonized root hairs to curl and form the ''Shepherds Crook''. The rhizobia then penetrate the root hairs and typically form a tubular structure called an ''infection thread''. Once the bacteria reach the root itself, they stimulate cortical cell divisions that lead to the formation of a nodule.

The data displayed in tables 3 - 6 indicate that at 25% concentration, the soils treated with aerobically/anaerobically fermented POME gave significantly ($P<0.05$) higher levels of growth compared to the mesocosms treated with higher (50, 75, and 100%) POME. In order words, POME application at low concentration induced observable positive effects on the plant growth and development. Such response may be attributed to the ability of POME to stimulate the decomposition of native organic matter in the subsisting soil/plant environment. POME amendment may have provided the microbes with the needed NO^3-N that stimulated soil organic matter degradation (Douglas *et al*. 2003) [7]. The decrease in measurements observed in mesocosms treated with higher concentration of aerobically and anaerobically fermented POME could arise from excess nitrate, phosphorus and organic matter leading to inhibition in the oxidative biogeochemical transformation in the soil (Prescott *et al*. 2001). Another important factor is the oily nature of the effluent which have potential for creating an anaerobic condition resulting in the reduced uptake of nutrients needed for the crop growth. The present results agree with Kitikum *et al*. (2000) and Osaigbovo and Orhue (2011) [18]. The 25% concentration load for POME application may have provided the optimum hydraulic load for effective soil reactions essential for crop growth. Excess application of wastewater to agricultural soils could lead to undesirable effects such as salinity, oxygen depletion and nutrient loss due to immobilization, denitrification and leaching (Searl *et al*. 1981) [23]. Warman and Termeer, (2005) [27] reported increases in crops following fermented waste application. Our results also agree with Yeop and Poop (1983) [29] who observed that land application of POME improved soil fertility and plant growth. Also, Orhue *et al*. (2005) [16] reported positive growth response in maize after application with brewery effluent. However, Wood et al. (1979) [28] noted some negative effects of POME which can be overcome by controlling the discharge or by application of small quantities of POME at a time. In the present study, the application of 25% treated POME improved the nodulation and growth processes in the plant more than the non-POME treated soil or the mesocosms that received higher POME concentrations. The latter might be due to the ability of the POME treated soils to retain water causing clogging of soil pores and hence water logging of the soil. Such condition leads to the death of vegetation because excess water in soil restricts microorganisms and their activities by preventing oxygen movement into and through the soil in sufficient quantity to meet with the oxygen demand of the organisms (Paul and Clarke, 1989) [21].

Table 3: Effect of different POME concentration on the leaf length (cm) of *Arachis hypogea* after weeks of treatment

	POME Concentration (%)								
Week	**Control**	**Aerobically Digested POME**				**Anaerobically Digested POME**			
		25	**50**	**75**	**100**	**25**	**50**	**75**	**100**
1	2.9 ± 0.07^{Ca}	2.8 ± 0.14^{Ca}	2.7 ± 0.07^{Ca}	2.6 ± 0.07^{Ca}	2.1 ± 0.21^{ABa}	2.7 ± 0.00^{Ca}	2.6 ± 0.07^{Ca}	$2.5 \pm 0.0.7^{BCa}$	1.9 ± 0.07^{Aa}
2	3.2 ± 0.07^{DEab}	3.0 ± 0.07^{DEab}	2.9 ± 0.00^{DEab}	2.8 ± 0.07^{BCDab}	2.6 ± 0.07^{ABCab}	2.9 ± 0.07^{CDEab}	2.7 ± 0.07^{BCDa}	2.5 ± 0.14^{ABa}	2.3 ± 0.07^{Ab}
3	3.4 ± 0.07^{EFab}	3.2 ± 0.00^{EFbc}	3.1 ± 0.07^{DEbc}	3.0 ± 0.07^{CDEb}	2.8 ± 0.14^{BCDb}	2.9 ± 0.00^{CDab}	2.8 ± 0.07^{BCab}	2.6 ± 0.07^{ABa}	2.5 ± 0.07^{Abc}
4	3.5 ± 0.21^{Cb}	3.5 ± 0.07^{Cc}	3.2 ± 0.14^{BCbc}	3.0 ± 0.14^{ABCb}	2.9 ± 0.07^{ABb}	3.1 ± 0.07^{ABCb}	2.8 ± 0.00^{ABab}	2.8 ± 0.21^{ABa}	2.6 ± 0.07^{Ac}
5	3.6 ± 0.21^{CDEb}	3.9 ± 0.07^{Ed}	3.3 ± 0.07^{CDc}	3.1 ± 0.07^{BCb}	2.9 ± 0.07^{ABb}	3.6 ± 0.14^{DEc}	3.0 ± 0.07^{ABCc}	2.9 ± 0.07^{ABa}	2.6 ± 0.00^{Ac}

KEY: Alphabets in capital letters = Mean difference significant between various %concentration of POME treatment

Alphabets in small letters = Mean difference significant within a particular %concentration of POME treatment

NOTE: Same capital letters are not statistically different among treatments by the Turkey test ($p<0.05$) and small lower cap letters are not statistically different among weeks by the Turkey test ($p<0.05$) ± standard deviation.

Table 4: Effect of different POME concentration on the leaf width (cm) *Arachis hypogea* after weeks of treatment

	POME Concentration (%)								
Week	**Control**	**Aerobically Digested POME**				**Anaerobically Digested POME**			
		25	**50**	**75**	**100**	**25**	**50**	**75**	**100**
1	2.10 ± 0.14^{Ca}	2.15 ± 0.07^{Ca}	2.00 ± 0^{BCa}	1.80 ± 0.14^{ABCa}	1.40 ± 0.14^{Aa}	2.10 ± 0^{Ca}	1.80 ± 0.14^{ABca}	1.50 ± 0.14^{ABa}	1.50 ± 0.28^{ABa}
2	$2.50 \pm 0.14^{Ca`}$	2.20 ± 0.14^{BCa}	2.05 ± 0.21^{ABCa}	2.00 ± 0.14^{ABCa}	1.70 ± 0.14^{ABa}	2.10 ± 0.14^{ABCa}	1.90 ± 0.14^{ABCa}	1.6 ± 0.14^{ABa}	1.50 ± 0.28^{Aa}
3	2.60 ± 0.28^{Ca}	2.30 ± 0.28^{ABa}	2.10 ± 0.14^{ABa}	2.00 ± 0.28^{ABa}	1.80 ± 0.14^{Aa}	2.20 ± 0.14^{ABa}	2.00 ± 0.14^{ABa}	1.70 ± 0.14^{Aa}	1.60 ± 0.14^{Aa}
4	2.70 ± 0.28^{Ba}	2.40 ± 0.28^{ABa}	2.20 ± 0.14^{ABa}	2.10 ± 0.28^{ABa}	1.80 ± 0.14^{Aa}	2.30 ± 0.14^{ABa}	2.10 ± 0.14^{ABa}	1.80 ± 0.14^{Aa}	1.70 ± 0.28^{Aa}
5	2.70 ± 0.14^{Ca}	2.50 ± 0.14^{BCa}	2.20 ± 0.14^{ABCa}	2.10 ± 0.14^{ABCa}	1.80 ± 0.28^{ABa}	2.40 ± 0.28^{ABCa}	2.10 ± 0.14^{ABCa}	1.80 ± 0.14^{ABa}	1.70 ± 0.28^{Aa}

KEY: Alphabets in capital letters = Mean difference significant between various %concentration of POME treatment

Alphabets in small letters = Mean difference significant within a particular %concentration of POME treatment

NOTE: Same capital letters are not statistically different among treatments by the Turkey test ($p<0.05$) and small lower cap letters are not statistically different among weeks by the Turkey test ($p<0.05$) ± standard deviation.

Table 5: Effect of different POME concentration on the stem length (cm) of *Arachis hypogea)* after weeks of treatment

	POME Concentration (%)								
Week	**Control**	**Aerobically Digested POME**				**Anaerobically Digested POME**			
		25	**50**	**75**	**100**	**25**	**50**	**75**	**100**
1	15.2 ± 0.14^{Fa}	15.0 ± 0.14^{Fa}	14.0 ± 0.28^{DEa}	12.8 ± 0.14^{Ca}	10.7 ± 0.28^{Ba}	14.5 ± 0.14^{EFa}	13.5 ± 0.28^{Da}	10.5 ± 0.14^{Ba}	7.8 ± 0.28^{Aa}
2	15.9 ± 0.14^{Eb}	16.2 ± 0.14^{Eb}	14.3 ± 0.14^{Da}	13.6 ± 0.14^{Cb}	12.7 ± 0.28^{Bb}	14.8 ± 0.14^{Da}	14.2 ± 0.14^{Dab}	12.5 ± 0.14^{Bb}	8.0 ± 0.28^{Aa}
3	22.4 ± 0.14^{Hc}	24.0 ± 0.14^{Ic}	17.6 ± 0.14^{Fb}	16.0 ± 0.14^{Ec}	13.8 ± 0.14^{Cc}	18.6 ± 0.14^{Gb}	14.9 ± 0.14^{Db}	13.3 ± 0.14^{Bc}	12.8 ± 0.14^{Ab}
4	23.2 ± 0.14^{Fd}	24.9 ± 0.28^{Gd}	18.7 ± 0.14^{Dc}	16.5 ± 0.14^{Ccd}	15.4 ± 0.14^{Bd}	22.6 ± 0.28^{Ec}	16.4 ± 0.14^{Cbc}	15.6 ± 0.14^{Bd}	13.1 ± 0.21^{Ab}
5	24.2 ± 0.14^{Ge}	26.5 ± 0.14^{He}	19.5 ± 0.14^{Ed}	16.8 ± 0.14^{Cd}	15.5 ± 0.14^{Bd}	23.0 ± 0.00^{Fc}	17.9 ± 0.14^{Dd}	15.9 ± 0.14^{Bd}	13.3 ± 0.28^{Ab}

KEY: Alphabets in capital letters = Mean difference significant between various %concentration of POME treatment

Alphabets in small letters = Mean difference significant within a particular %concentration of POME treatment

NOTE: Same capital letters are not statistically different among treatments by the Turkey test ($p<0.05$) and small lower cap letters are not statistically different among weeks by the Turkey test ($p<0.05$) ± standard deviation.

Table 6: Effect of different POME concentration on the root length (cm) *Arachis hypogea* after weeks of treatment

	POME Concentration (%)								
Week	**Control**	**Aerobically Digested POME**				**Anaerobically Digested POME**			
		25	**50**	**75**	**100**	**25**	**50**	**75**	**100**
1	5.5±0.14^{Da}	5.3±0.14^{CDa}	5.1±0.14^{CDa}	3.0±0.14^{Ba}	2.1±0.14^{Aa}	5.2±0.14^{CDa}	5.0±0.00^{Ca}	2.8±0.00^{Ba}	2.0±0.00^{Aa}
2	5.9±0.14^{Ga}	5.8±0.14^{FGa}	5.4±0.00^{EFa}	4.7±0.14^{Db}	4.0±0.14^{Cb}	5.6±0.00^{EFGab}	5.2±0.14^{Ea}	3.2±0.14^{Bab}	2.2±0.14^{Aa}
3	7.0±0.14^{EFb}	7.2±0.00^{Fb}	6.6±0.14^{Eb}	5.5±0.14^{Dc}	4.9±0.14^{Cc}	5.8±0.14^{Db}	5.4±0.14^{Da}	3.7±0.14^{Bb}	2.4±0.14^{Aa}
4	7.2±0.00^{FGb}	7.6±0.14^{Gb}	6.8±0.14^{EFbc}	5.7±0.14^{CDcd}	5.3±0.14^{Ccd}	6.5±0.14^{Ec}	5.9±0.14^{Db}	4.6±0.14^{Bc}	3.9±0.14^{Ab}
5	8.1±0.14^{Fc}	11.0±0.14^{Gc}	7.2±0.14^{Ec}	6.2±0.00^{Dd}	5.7±0.14^{Cd}	7.8±0.00^{Fd}	6.9±0.14^{EC}	5.1±0.14^{Bc}	4.1±0.14^{Ab}

KEY: Alphabets in capital letters = Mean difference significant between various %concentration of POME treatment

Alphabets in small letters = Mean difference significant within a particular %concentration of POME treatment

NOTE: Same capital letters are not statistically different among treatments by the Turkey test ($p<0.05$) and small lower cap letters are not statistically different among weeks by the Turkey test ($p<0.05$) ± standard deviation.

4. Conclusion

The results of the present study indicate that soil physico-chemical parameters are altered at the application of POME. It further shows that use of fermented POME promoted soil quality and improved plant growth and characteristics although excessive application beyond plant requirement and absorptive capacity of soil could be dangerous to the plant health and the soil ecosystem. The effects POME has on soil properties would help farmers mostly in rural areas to improve food production through expanding their understanding on the importance of POME treatment and the application of required quantities as conditioners and organic fertilizers during farming.

5. References

1. Adeniyan ON, Ojo AO, Akinbode OA, Adediran JA. Comparative study of different organic manures and NPK fertilizer for improvement of soil chemical properties and dry matter yield of maize in two different soils. Journal of Soil Science and Environmental Management. 2011; 2(1):9-13.
2. Ahmad A, Ismail S, Bhatia S. Water recycling from palm oil mill effluent (POME) using membrane technology. Desalination. 2003; 157:87-95.
3. Awotoye OO, Dada AC, Arawomo GAO. Impact of palm oil processing effluent discharging on the quality of receiving soil and rivers in south western Nigeria. Journal of Applied Sciences Research. 2011; 7(2):111-118.
4. Buri MM, Wakatsuki T, Issaka RN. Extent and management of low pH soils in Ghana. Soil Science and Plant Nutrition. 2005; 51(5):755-759.
5. Cheng HP, Walker GC. Succinoglycan is required for initiation and elongation of infection threads during nodulation of alfa alfa by *Rhizobium meliloti*. Journal of Bacteriology. 1998; 180: 5183-5191.
6. Dhanya G, Jaya D. Pollutant removal in wastewater by vetiver grass in constructed wetland system. International Journal of Engineering Research and Technology. 2013; 2(12):1361-1368.
7. Douglas JT, Aitkin MN, Smith CA. Effects of five non-agriculture organic waste on soil composition, and on the yield and nitrogen recovery of Italian rye grass. Soil Use and Management. 2003; 19:135-138.
8. Ezemonye, LIN., Ogeleka DF, Okieimen FE. Lethal toxicity of industrial chemicals to early life stages of *Tilapia guineensis*. Journal of Hazardous Materials. 2008; 157(1):64-68.
9. Hutchings NJ. The availability of nitrogen in liquid sewage sludge applied to grassland. Journal of Agricultural Science Cambridge. 1984; 102:703-709.
10. Ngan MA, Zajima Y, Asahi M, Junit H. A novel treatment processes for palm oil mill effluent. PORIM Technology, 1996.
11. Nwoko CO, Ogunyemi S. Effect of palm oil mill effluent (POME) on microbial characteristics in a humid tropical soil under laboratory conditions. International Journal of Environmental Science and Development. 2010; 1(4):307-314.
12. Okwute OL, Isu NR. Impact analysis of palm oil mill effluent on the aerobic bacterial density and ammonium oxidizers in a dumpsite in Anyigba, Kogi State. African Journal of Biotechnology. 2007; 6(2):116-119.
13. Olorunfemi D, Emoefe EO, Okieimen FE. Effect of cassava processing effluent on seedling height, biomass and chlorophyll content of some cereals. Research Journal of Environmental Sciences. 2008; 2(3):221-227.
14. Onwusi CC, Nwuche CO. The impact of palm oil mill effluent (POME) application on the rhizosphere heterotrophic population, nitrogen fixing bacteria and enzyme activity of an agricultural soil. Nigerian Journal of Biotechnology. 2017; 34:1-11.
15. Onyia CO, Uyub AM, Akunna JC, Norulaini NA, Omar AKM. Increasing the fertilizer value of palm oil mill sludge: bioaugmentation in nitrification. Water Science and Technology. 2001; 44(10):157-162.
16. Orhue ER, Osaigbovo AU, Vwioko DE. Growth of maize (zea mays L.) and changes in some chemical properties of an ultisol amended with brewery effluent. Journal of Biotechnology. 2005; 4(9):973-978.
17. Orji MU, Nwokolo SO, Okoli I. Effects of palm oil mill effluent on soil Microflora. Nigerian Journal of Microbiology. 2006; 20(2):1026-1031.
18. Osaigbovo AU, Orhue ER. Effect of palm oil mill effluent on some soil chemical properties and growth of maize (Zea Mays L). Nigerian Journal of Agriculture, Food and Environment. 2011; 7(3):51-54.
19. Parihar DK. Production of lipase utilizing linseed oil cake as fermentation substrate. International Journal of Science, Environment and Technology. 2012; 1(3):135-143.
20. Pascual I, Antolin AC, Garcia C, Polo A, Sanchez-Diaz M. Effect of water deficit on microbial characteristics in

soil amended with sewage sludge or inorganic fertilizer under laboratory conditions. Bio resource Technology. 2007; 98:29-37.
21. Paul EA, Clark FE. Soil Microbiology and Biochemistry. Academic Press Incorporated San Diego, California, 1989, pp.11-234.
22. Piotrowska A, Iamarino G, Rao MA, Gianfreda L. Short-term effects of olive mill waste water (OMW) on chemical and biochemical properties of a semiarid Mediterranean soil. Soil Biology and Biochemistry. 2006; 38:600-610.
23. Searle PGE, Comudom Y, Shedden DC, Nance RA. Effect of maize/legume intercropping systems and fertilizer nitrogen on crop yields and residual nitrogen. Field Crops Research. 1981; 4:133-145.
24. Serna MD, Pomares F. Nitrogen mineralization of sludge-amended soil. Bio resource Technology. 1992; 39(3):285-290.
25. Sims JT. Nitrogen mineralization and elemental availability in soils amended with co-composted sewage sludge. Journal of Environmental Quality. 1990; 19:669-675.
26. Vadakattu G, Paterson J. Free living bacteria lift soil nitrogen supply. Farming Ahead. 2006; 169:40.
27. Warman PR, Termeer WC. Evaluation of sewage sludge, septic waste and sludge compost applications to corn and forage: yields and N, P and K content of crops and soils. Bioresource Technology. 2005; 96:955-961.
28. Wood BJ, Pillai KR, Rajaratnam JA. Palm oil mill effluent disposal on land. Agricultural Wastes. 1979; 1:103-12.
29. Yeop KH, Poop KC. Land application of plantation effluent. Proceedings of the Rubber Research Institute of Malaysia on oil palm by product utilization, Kuala Lumpur, 1983.