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Effect of Palm Oil Mill Effluent (POME) on Microbial Characteristics in a Humid Tropical Soil under Laboratory Conditions.

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Abstract—**Palm Oil mill Effluent (POME), a by-product of palm oil mills, is produced in large quantity in some West-African countries. Although it is a land and aquatic pollutant when discharged directly into the environment, it is amenable to biodegradation. Conversion of POME to organic fertilizer can be a sustainable strategy for its disposal only when its effects on soil microbial and biochemical properties are known. An experiment was conducted to establish the effect of 20 days fermented POME on soil chemical, microbial and biochemical properties in a humid soil under laboratory conditions. The soil received 0(control), 50 and 90 ml per 200 g soil (corresponding to 0 m^3/ha, 30 m^3/ha and 70 m^3/ha, respectively). Available N, P, K and total N, electrical conductivity (EC), total organic carbon significantly increased in POME amended soil, especially at 40 and 60 days incubation periods. Similarly, soil microbial properties (soil microbial carbon, basal respiration and metabolic quotient) were also increased in the treated soil during the incubation period. Enzyme activities were equally increased on soil amended with fermented POME. However, there was no significant correlation between enzyme activities, microbial carbon and total nitrogen. But basal respiration positively influenced dehydrogenase and urease activities. These data confirmed that fermented POME material could enhance soil microbiological activities which ultimately increase soil fertility.**

Index Terms—**Organic-amendment, soil-biochemistry, fermentation, soil-nutrient and waste-management.**

I. Introduction

The use of wastes, such as sewage sludge, Palm Oil Mill Effluent (POME) and Olive Mill Effluent(OME) etc in agriculture and for land reclamation are common practice in regions with abundant supply especially for irrigation, soil conditioning, amendment and conservation purposes [1]-[3]. Palm oil production requires input of large quantity of water which is eventually discharged as waste effluent. The addition of effluent materials with high organic matter content will help replenish the soil for sustainable agriculture.

Palm oil mill effluent application to soil can result to some beneficial soil chemical and physical characteristics, such as increases in organic matter, organic carbon, major nutrients (e.g N,P), water-holding capacity and porosity [4], [1], [5]. However, it brings about undesirable changes such as decreases in pH, and increases in salinity etc.[6]. These effects occur very slowly and need many years to provide significant results. Soil microbiological and biochemical properties have been considered early and sensitive indicators of soil changes and can be used to predict long-term trends in the quality of soil [7]. Soil microbial properties are equally affected by environmental factors [8], for example, [9] reported that high rate of inorganic fertilizer application suppresses microbial respiration and dehydrogenase activity. Other factors as increases in salinity or decreases in water availability may also reduce biological activity [10].

Palm oil mill effluent contains high organic load, substantial amounts of plant nutrients and represent a low-cost source of plant nutrients when fermented [6], [11]. It is generally believed that the toxicity effect of POME is due to presence of phenols and other organic acids which are responsible for phytotoxic effect and antibacterial activity [12], [3]. However, the polyphenolic fraction degrades with time and partially transforms in humic substances [13]

Little information is known on the impact of POME on the biochemical and microbial properties of soil. Studies show that effects of wastes supplied to soil occurred mainly in the first weeks after amendment [14], [2] [15]. The present work was aimed at evaluating; under laboratory conditions the short-term influence of different application rates of 20 days fermented POME on soil biochemical and microbial properties.

II. Materials and Methods

A. Soil and POME

The soil used for the study was classified as Ultisol as revealed by its low percentage base saturation (>35%). The particle size distribution analyses in the top soil (0-15cm) showed that the soil is loamy sand. The soil was obtained from an agricultural soil in Owerri, southeastern Nigeria, exposed to humid tropical climate (annual rainfall of 2963 mm, annual average temperature 30-33 ^oC and relative humidity of 71.3%). The field-moist samples were sieved (< 2mm), delivered in sealed plastic bags to the laboratory under refrigerated conditions and stored at 4^oC until analysis. The result of pre-soil characteristics is shown in (Table 1.0). Palm oil mill effluent (POME) was obtained from ADAPALM Ltd owned by Imo state government and allowed to ferment for 20 days in an enclosed room to allow for decrease of phytotoxic compounds. The characteristic of the effluent is shown in Table 1.0. Chemical oxygen demand determination was based on closed reflux dichromate oxidation colorimetric method and was read out in DR 2000 spectrophotometer as explained in detail in [16].

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Samples for BOD_5 measurements were prepared according to a modified method explained in [16]. 2-Chloro-6 trichloro-methyl pyridine was used to inhibit nitrification as stipulated by the procedure. The apparatus used was the Lovibond BOD IR-sensomat, which consists of an IR-pressure sensor acting as the measurement device, BOD-sensomat and stirring system. Each sample was collected in a 500 ml BOD flask and was filled completely and covered satisfactorily with foil cap and left for a 5-day period. The resultant carbondioxide from microbial respiration is absorbed with potassium hydroxide (KOH), which creates a decrease of the air pressure in the BOD flask. The pressure decrease is detected by the IR-sensor, logged into the BOD-sensor and converted directly in mg/L of BOD. Suspended solid was determined gravimetrically by evaporating to dryness 100 ml of unfiltered sample (effluent) and heating to constant weight.

TABLE 1.0 CHARACTERISTICS OF THE SOIL AND POME

Parameters	Soil	POME
pH(H_2O)	5.9 ± 2.3	4.5 ± 2.1
Electrical conductivity (dS m^{-1})	0.27 ± 0.03	0.19 ± 0.021
Total organic carbon (g kg^{-1})	6.4 ± 2	256 ± 24
Total N (g kg^{-1})		35 ± 2.1
Total K (g kg^{-1})		5.4 ± 2.1
Total P (g kg^{-1})		13.2 ± 3.7
Avail. N (mg kg^{-1})	7.9 ± 0.3	
Avail. P (mg kg^{-1})	27.3 ± 2	
Avail. K (mg kg^{-1})	153.5 ± 12	
C/N		7.3
BOD_5 (mg l^{-1})		16307.2 ±13.9
COD (mg l^{-1})		13452.0 ±45
TSS (mg l^{-1})		11977.5± 2.6

POME= palm oil mill effluent, BOD= biochemical oxygen demand, COD= chemical oxygen demand, TSS= total suspended solid.

B. Experimental design

The soil (200 g) was put in plastic pots and treated with 20 days fermented POME at two different concentrations 50 and 90 ml per 200 g soil (equivalent of 30 and 70 m^3/ha, respectively). Soil without treatment served as control. Distilled water was used to balance the moisture content of the 50 ml/200 g and control pot to 50 % water holding capacity (WHC) of all the experimental units. Each treatment was replicated three times. All the samples were incubated under controlled conditions of humidity and temperature at 25°C in the dark, for 25, 40 and 60 days. At each day, samples were collected from the three pots (viz 30 m^3/ha, 70 m^3/ha and 0 m^3/ha (control)) and divided into four sub samples for all physico-chemical, biochemical and microbial analyses.

C. Analytical measurements

The principal soil physicochemical properties after POME application to soil were determined by standard methods as explained in methods of soil analysis, [17] and each sample was analyzed in triplicates. The pH was measured in an aqueous solution (1:2.5 w/v in soil and 1:5 in effluent) and electrical conductivity (EC) was measured in 1:1 and 1:5 dilutions for soil and effluent. Total organic carbon (TOC) was determined by oxidation with $K_2Cr_2O_7$ in a concentrated H_2SO_4 medium followed by measurement of dichromate excess using $(NH_4)_2Fe\ (SO_4)_2$ [18]. Total N concentration for soil and effluents were also determined using the macro-kjeldahl method, available NO_3-N and NH_4-N were extracted with 1 M KCl and determined spectrophotometrically in filtered extracts. Total P and K were analysed by inductively coupled Plasma (ICP) after acid digestion.

Soil microbial biomass (MB-C) was determined by fumigation of the samples with C_5H_5OH-free $CHCl_3$ and extraction with 0.5 M K_2SO_4. The extracted C content was determined by dichromate oxidation [19]. Basal respiration (CO_2 evolution without substrate addition) was determined by placing subsamples of moist soil (30 % water holding capacity- WHC)) (20 g oven dry soil) in 15 ml vessels and incubated at 25°C and CO_2 evolved over 72 hr was trapped in 0.05 M NaOH solution. Carbonates were precipitated with 0.5 M $BaCl_2$ and the residual NaOH was titrated with 0.05 M HCl using phenolphthalein indicator. All samples were corrected for the CO_2 content of blanks.

The metabolic quotient (qCO_2) was calculated from the basal respiration rate and the amount of microbial biomass C (MB-C) according to the formula of [20]. The ratio MB-C (mg) /TOC (g) was also calculated.

Urease (E.C 3.5.1.5) activity was determined using urea (1M) as a substrate [21]. Dehydrogenase (E.C. 1.1) activity was measured by mixing 1.2 g of soil with 1 ml of buffered tetrazolium salts (TTC) solution, according to [22]. Protease (*N*-α-benzoyl-*L*-argininamide (BAA) protease) activity was measured following the method of [23]. Phosphatase and *β*-glucosidase activities were determined using *p*-nitrophenyl phosphate disodium (0.115 M) and *p*-nitrophenyl glucopyranoside (0.05 M), as substrates [24].

D. Statistical analysis

All results were expressed on an air dry soil basis and based on three replicates. Data collected were subjected to

analysis of variance (ANOVA) using GenStat discovery edition 3 and significant means compared using Fisher least significant difference at 5 %. All the tables presented include standard errors of the data.

III. Results

A. Chemical characteristics of soil, POME and soil amended with POME.

The soil had slightly acidic character (5.6 ± 2.3) table 1.0 with electrical conductivity of 0.27 ± 0.03 ds m^{-1}). There was poor organic C content (6.4± 2.0 g kg^{-1}) and soil available N, P and K were 7.9 ± 0.3 mg kg^{-1}, 27.3 ± 2.0 mg kg^{-1} and 153.5 ± 12 mg kg^{-1}, respectively.

Palm oil mill effluent samples were acidic (4.5 ±2.1) with moderate electrical conductivity(0.19±0.02 ds m^{-1}) it has high level of organic carbon (256 ±24) and total N. POME also had moderate levels of total K and P. Biochemical oxygen demand , chemical oxygen and total suspended solid were reasonably high as expected of effluent with high organic content.

The addition of effluent to soil had different effects to the physicochemical characteristics of soil as influenced with time (Table 2.0). Application of 74 m^3/ha of POME decreased pH from 5.6 to 4.8 at 25 days incubation period but gradually increased to 5.6 at 60 days. There was no significant pH change at 30 m^3/ha POME application and control. Period of incubation did not significantly affect pH change in the application rates. POME application enhanced soil electrical conductivity and total organic carbon. However, these parameters decreased as the time of incubation increased. Total nitrogen was not significantly affected by number of days of incubation and as POME concentration increased. Nitrogen, phosphorus and potassium availability were improved on application of POME especially at 70 m^3/ha application rate (Table 2.0).

B. Microbial properties

The incorporation of POME into soil increased microbial biomass carbon, basal respiration and metabolic quotient (qCO_2) (Table 3.0). After amendment, microbial biomass carbon increased at a steady rate till 40 days incubation period before experiencing slight decrease at 60 days incubation. There were about 3 and 2 fold increases on microbial biomass C compared to control at high and low dose applications, respectively at the highest MB-C value. No significant relationships existed between MB-C and enzyme activities (Table 5.0). POME amendment significantly affected basal respiration in the entire incubation period. At high dose application

(70 m^3/ha) basal respiration ranged between (34.2-35.1 $\mu gC\text{-}CO_2 g^{-1}$). Basal respiration increased as the time of soil incubation increased from 25 to 60 days and at time increased with

TABLE 2.0. Chemical Properties of Control and POME amended soil

Parameter	Treatment	incubation times (days)			s.e	$LSD_{0.05}$
		25	40	60		
pH (H_20)	0m^3/ha	5.8	5.7	5.8	0.03	0.71
	30 m^3/ha	5.4	5.5	5.6	0.12	0.82
	70 m^3/ha	4.8	5.4	5.6	0.23	0.43
	s.e	0.03	0.12	0.04		
	$LSD_{0.05}$	0.23	0.43	0.34		
EC (dS m^{-1})	0 m^3/ha	0.31	0.28	0.27	0.04	0.12
	30 m^3/ha	0.64	0.43	0.38	0.23	0.23
	70 m^3/ha	1.23	0.65	0.71	0.45	0.34
	s.e	0.12	0.23	0.32		
	$LSD_{0.05}$	0.54	0.23	0.46		
TOC(g kg^{-1})	0 m^3/ha	10.6	11.2	11.7	0.32	0.04
	30m^3/ha	14.5	14.2	13.6	0.34	1.04
	70m^3/ha	17.5	16.3	14.5	0.21	0.12
	s.e	1.21	0.87	0.78		
	$LSD_{0.05}$	2.4	2.56	4.65		
TN (g kg^{-1})	0 m^3/ha	1.3	1.6	1.6	0.1	0.3
	30m^3/ha	1.4	1.5	1.4	0.02	0.6
	70m^3/ha	1.5	1.5	1.7	0.02	0.6
	s.e	0.02	0.04	0.05		
	$LSD_{0.05}$	0.7	0.8	0.7		
Avail. N (mg kg^{-1})	0m^3/ha	40.6	41.2	40.2	0.34	1.3
	30m^3/ha	41.4	43.2	43.2	0.21	1.8
	70m^3/ha	44.3	46.3	50.3	0.32	2.4
	s.e	0.12	0.23	0.32		
	$LSD_{0.05}$	3.2	3.8	4.2		
Avail. P(g kg^{-1})	0m^3/ha	122.3	132.1	134.4	0.23	11.4
	30m^3/ha	143.2	153.1	154.3	0.55	12.4

	70m^3/ha	150.3	155.3	160.2	0.45	12.7
	s.e	1.2	1.3	1.23		
	LSD $_{0.05}$	25.3	22.3	25.8		
Avail. K(g kg^{-1})	0m^3/ha	89.7	90.2	89.5	0.34	2.34
	30m^3/ha	91.2	90.7	92.1	0.43	2.23
	70m^3/ha	94.3	94.7	95.7	0.23	2.12
	s.e	2.31	2.12	2.15		
	LSD $_{0.05}$	4.6	6.8	4.6		

EC= electrical conductivity, TN = Total nitrogen, TOC= total organic carbon.

Dose of application (Table 3.0). High basal respiration corresponded with increased MB-C production except at 40 days incubation where low basal respiration gave high MB-C. Basal respiration significantly correlated with dehydrogenase (r=0.88) and urease (r=0.45) activities during the incubation period (Table 5.0). Microbial metabolic quotient (qCO_2) was significantly affected by POME soil amendment in the entire experiment. Metabolic quotient also significantly correlated with dehydrogenase and urease activities. Negative correlation only existed with β-glucosidase enzyme. The ratio MB-C: TOC was significantly affected by POME amendment. However, application dose did not significantly affect MB-C: TOC. At dose 70 m^3/ha MB-C: TOC ranged between 36 to 44.7 and 30 m^3/ha ranged between 31.7 to 34.6. The ratio MB-C: TOC increased as duration of incubation increased.

C. Soil enzyme activity.

Soil POME amendment improved the activities of some enzymes during the incubation period (Table 4.0). Compared to control soil, the addition of POME promoted a significant increase of about 6-fold with 70 m^3/ha dose especially of β-Glu, Phos and DH shortly after application (25 days). Hydrolases (Protease-BAA, phosphatase and β-glucosidase) recorded a steady increase in activity through out the incubation period irrespective of the dose applied. However, Urease and dehydrogenase recorded an increase up till 25 days incubation and activity falls and then stabilizes at 60 days (Table 4.0). At high dose application there was no significant differences in Urease, Protease and Phosphatase activities in all assayed samples. Available N negatively correlated with Phosphatase, Protease, and urease except *β*-glucosidase with positive correlation (Table 5.0). DH and UR positively affected qCO_2, basal respiration and pH however UR negatively affected avail. N. From the result, microbial carbon and total nitrogen did not affect enzyme activities throughout the incubation period (Table 5.0).

TABLE 3.0. MICROBIAL PROPERTIES OF CONTROL AND POME AMENDED SOIL

Parameter	Treatment	incubation times (days)				
		25	40	60	s.e	LSD $_{0.05}$
Soil MB-C(µg C g^{-1} soil)	0 m^3/ha	210.2	220.2	217.4	0.13	10.2
	30m^3/ha	460.1	473.3	470.2	0.37	8.67
	70m^3/ha	630.1	650.5	648.7	0.32	7.84
	s.e	0.23	0.43	0.75		
	LSD $_{0.05}$	30.2	50.2	64.2		
Basal respir.(µg C-CO_2 g^{-1} soil h^{-1})	0m^3/ha	18.9	19.2	19.3	0.03	0.18
	30m^3/ha	23.4	25.6	30.5	0.04	2.7
	70m^3/ha	34.2	34.7	35.1	0.12	1.9
	s.e	0.03	0.12	0.23		
	LSD $_{0.05}$	5.6	8.9	12.3		
qCO_2(ngCO_2-C µg^{-1} h^{-1})	0m^3/ha	1.2	1.5	1.3	0.02	0.43
	30m^3/ha	1.5	1.4	1.5	0.01	0.32
	70m^3/ha	2.2	2.4	2.3	0.12	0.43
	s.e	0.02	0.03	0.12		
	LSD $_{0.05}$	2.1	1.3	1.2		
MB-C(mg)/TOC(g)	0m^3/ha	19.8	20	18.6	0.34	1.3
	30m^3/ha	31.7	33.3	34.6	0.41	2.4
	70m^3/ha	36	40	44.7	0.23	3.7
	s.e	0.23	0.32	0.43		
	LSD $_{0.05}$	12.4	10.6	23.6		

MB-C = microbial carbon, qCO_2= respiratory quotient, TOC= total organic carbon

IV. Discussion

Results presented here showed that several chemical and biochemical properties of the investigated soil changed in response to the application of POME. Organic amendment produced a decrease in pH; this may have resulted from nitrification activities of NH_4-N components of POME [3], [25]. An increase in EC within 25 days of application has been previously reported [4], [1], [26] (Table 2.0), and may be due to the high amount of soluble salts present in POME and to the presence of NO_3-N and P in soil. The increase in available N, P and K could be attributed to the acidic nature of POME and its capacity to increase salinity and decrease plant available magnesium [27]. In addition, the increase in available K in the two doses applied through out the incubation period suggest that K may have played a vital role in the oxidative transformation of toxic phenolic compounds in POME. In this process, soluble monomeric phenols are oxidized, and further polymerized, while soil K are reduced to their soluble, extractable form K^+ [13] . The reduction of the concentration of soluble toxic phenolic compounds was reflected in the increased microbial biomass C content and enzymatic activity in the treated soil. Fresh input of aerobically fermented POME with degraded and degradable C and N substrates resulted in high levels of extracted C and N and led to increase in microbial activity. Soil microbiological and biochemical properties respond rapidly to small changes that occur in soil, thereby providing immediate information on changes in soil quality. This is because soil microbial activity has a direct influence on soil fertility [28], [29], [30]. Microbial biomass C and basal respiration increase observed in the POME treated soil could be as a result of addition of easily degradable materials, which stimulate native microbial activity and addition of exogenous microorganisms originating from the POME material [31]-[33].

Metabolic quotient (qCO_2) is a measure of respiration rate per unit microbial C and this can be used to evaluate the effects of environmental conditions [20], [13] and determine substrate utilization efficiency [34]. High qCO_2 can result from an increase in availability of labile C source per unit biomass, a shift in microbial populations (e.g. fungal to bacterial biomass ratio [35] and / or increased proportion of active biomass [36]. Addition of POME produced an increase of qCO_2 in both low and high rate applications which indicates high respiration per unit of biomass in order to survive in the stress condition. The positive correlations found between dehydrogenase activity and soil basal respiration as well as with qCO_2 and extractable organic matter components (TOC and TN) support the fact that the soil amendment enhanced microbial activity. Furthermore, the high MB-C/TOC ratio confirms the above result. Conversely, organic C and N are the main constituents of the soil organic matter, and as such they may represent a substrate for enzyme degradation. [37] Reported that dehydrogenase and soil respiration reflects the total oxidative activity of soil micro flora and microbial biomass properties much more sensitive indicators of changing soil conditions than is the total organic matter. Although no absolute values have been defined as healthy or unhealthy [38], high values of MB-C/TOC quotient suggests good environmental condition for the establishment of many microorganisms. Usually, the lower the ratio, the lower the tendency of the organic matter to be mineralized [39].

The toxic nature of POME was probably responsible for the negative effects observed for some properties at early stage of incubation (<25 days) especially at high dose applications. For example, there was distinct reduction in dehydrogenase activity with time of incubation probably because the POME put the microbial population under stress, thereby frustrating the beneficial effects of the organic substrate supply. Additionally, the decomposition of POME by soil microbes could have induced oxygen depletion in the surface soil, thereby inhibiting aerobic microbial activity.

These toxic effects, the greatest probably occurring immediately after POME addition, were reflected by high values of the metabolic quotient qCO_2, often considered as an index to measure microbial stress in soil [20], [36]. Microorganisms ordinarily respond to this hostile environment by developing defence mechanisms by increasing their respiration per unit of biomass [20]. However, increased qCO_2 may also result upon organic matter addition to soil and its variations usually depend on the initial nutrient status (stressed or non-stressed) of the soil [36]. It is expected that qCO_2 values will fall with time and stabilize probably due to protective and buffering capacity of the soil [39].

The study of different hydrolase enzyme activities is important since they indicate the potential of a soil to carry out specific biochemical reactions, and are important in maintaining soil fertility [40]. Urease and Protease (that hydrolyses *N*-α-benzoyl-L-argininamide) act in the hydrolysis of organic to inorganic nitrogen, the former using urea–type substrate and the latter simple peptidic substrates. Phosphatase catalyses the hydrolysis of organic phosphorus compounds to phosphates. *β*–Glucosidase hydrolyse *β*-glucosidase in soil or in decomposing plant residues [41], [40].

TABLE 4.0. Enzyme activities in control and POME treated soil

Parameter	Treatment	incubation time (days)				
		25	40	60	s.e	$LSD_{0.05}$
Urease (UR)(μmol NH^+_4 $g^{-1}h^{-1}$)	0 m^3/ha	1.3	1.2	1.4	0.21	0.7
	30 m^3/ha	1.7	2.1	2.3	0.09	0.6
	70 m^3/ha	3.3	3.6	3.5	0.24	1.2
	s.e	0.23	0.34	0.21		

	$LSD_{0.05}$	1.4	1.7	1.5		
Dehydrogenase (DH) (µg INTF g^{-1})	$0m^3$/ha	8.5	9.6	9.6	0.21	0.54
	$30m^3$/ha	15.7	13.5	13.4	0.32	0.78
	70 m^3/ha	53.3	52.7	50.6	0.54	0.43
	s.e	2.4	3.4	3.1		
	$LSD_{0.05}$	12.1	15.2	14.3		
Protease(BAA)(µmol NH_3^+ g^{-1} h^{-1})	$0m^3$/ha	0.37	0.4	0.8	0.34	1.3
	$30m^3$/ha	0.6	0.8	0.9	0.43	0.4
	70 m^3/ha	1.6	1.6	1.76	0.21	0.6
	s.e	0.23	0.54	0.21		
	$LSD_{0.05}$	0.2	0.8	0.5		
Phosphatase (µmol PNP g^{-1} h^{-1})	$0m^3$/ha	32.6	33.5	34.2	0.21	6.7
	$30m^3$/ha	76.3	78.6	80.4	0.32	10.6
	70 m^3/ha	176.4	180.5	196.5	0.32	20.3
	s.e	2.6	3.6	3.9		
	$LSD_{0.05}$	40.5	67.5	79.4		
β-Glucosidase (µmol PNP g^{-1} h^{-1})	$0m^3$/ha	30.3	35.5	40.3	0.23	2.6
	30m3/ha	150.5	155.3	154.6	0.32	6.8
	70 m3/ha	230.4	233.3	243.3	0.64	10.4
	s.e	2.5	3.12	2.32		
	$LSD_{0.05}$	34.2	23.2	32.1		

There was considerable increase in hydrolase activity in the POME amended soil relative to control especially Phosphatase and *β*-glucosidase activities, irrespective of dose and duration of incubation. The regular increase of *β*-glucosidase with time in POME amended soils could indicate achievement of a capability of the soil to utilize carbohydrate material present in POME. Moreso, *β*-glucosidase is mostly produced by fungi [15], thus, its increased activity could suggest a shift between the proportions of fungi and bacteria in favour of fungi at the end of incubation. This hypothesis seems also to be supported by the large increase of the microbial C/N ratio in organic amended soil (Table 2 and 3). High microbial C/N ratios are indicative of high proportions of fungi over bacteria.

TABLE 5.0. CORRELATION MATRIX BETWEEN SELECTED SOIL MAJOR PROPERTIES

	MB-C	TOC	qCO_2	basal resp.	Avail.N	TN	pH
β-Glu	0.231	0.02	-0.34	-0.34	0.87**	-0.12	0.52**
Phos	0.021	-0.21	0.32	0.32	-0.56**	-0.211	-0.56
prot	0.14	-0.22	0.47	0.467*	-0.51**	-0.14	-0.26
DH	-0.32	0.67**	0.94***	0.88***	-0.27	0.03	0.622 **
UR	-0.211	0.47	0.74***	0.45*	-0.76**	-0.21	0.52**

β-Glu= β-glucosidase, Phos= Phosphatase, Prot= Protease, DH= dehydroegenase, UR=Urease
MB-C= microbial carbon, TOC= total organic matter, qCO_2= respiratory quotient.

V. Conclusions

Microbial activity in POME amended soils was increased under laboratory-controlled conditions irrespective of dose and duration of incubation. However, microbial and biochemical properties examined indicated an initial stress on microbes especially at early stage of incubation, but was quickly stabilized due to buffering capacity of soil. This work shows that the application of fermented POME to soils improved some soil microbiological activities related to C, N and P cycling under humid conditions. We recommend judicious application rates to control soil salinity, which may inhibit microbial activity under these conditions.

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