Improving Crude Oil Contaminated Soil with Organic Amendments: Effect of Oil Palm Bunch Ash and Dried Poultry Litters on Soil Properties and Cassava Growth and Yields

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ABSTRACT: In this study, onsite field experiments were carried out to evaluate the effects of amending a crude oil polluted soil with oil palm fruit bunch ash (OPFBA), dried poultry litters (DPL), soil bacterial, physico-chemical properties, as well as the growth and tuber yield of cassava (Manihot esculenta CRANTZ) grown on the amended soils using standard techniques. Results of autotrophic bacteria counts revealed that nitrogen fixing bacteria (NFB) populations in soils treated with OPBA+DPL combined, OPBA and DPL singly, recorded high bioloads in the magnitude of 10^5, 10^3, 10^5 CFU/g of soil respectively, whereas the group mean population was lower in the control soil (10^3 CFU/g). Similar trends were observed for SRB, PSB, and THB. Results of aggregate growth showed that while the mean plant heights and number of nodes increased, stem girth and leaf area were observed to decrease in 2017 when compared with those of 2016. Apart from number of tubers and weights that showed increase under all amendment treatments, tuber girth and length decreased under DPL amendments in 2017. The average findings of several chemical and physical characteristics of crude oil polluted soil after amendments and subsequent cultivation demonstrated that the addition of DPL and OPBA fructifies the soil by increasing reduced or lost qualities. When the amendments were used, the concentrations of organic carbon, accessible phosphorus, Ca, Mg, Na, and K were greatly enhanced, while the Total Petroleum Hydrocarbon (TPH) content was significantly reduced. In this study, the application of combination DPL + OPBA yields the greatest results in terms of ameliorating the impacts of crude oil in cultivable soils, as it increases fertility parameters for better cassava production in Niger Delta soils. The technology has been shown to be cost effective, efficient, and environmentally friendly, as well as capable of resolving waste management issues.

Cite this paper as: OSU, S. R; UDOFIA, G. E; NDAEYO, N. U. (2022). Improving Crude Oil Contaminated Soil with Organic Amendments: Effect of Oil Palm Bunch Ash and Dried Poultry Litters on Soil Properties and Cassava Growth and Yields. *J. Appl. Sci. Environ. Manage.* 26 (10) 1647-1656

Keywords: Organic amendment; Soil properties; Autotrophic bacteria; Productivity; Cassava; Polluted soil.

The Niger Delta region of Nigeria has over the years witnessed massive environmental degradation, top among which is degradation of soil quality owing to crude oil spillage which subsequently affects the growth of plants (Osu *et al.,* 2006 and Osu *et al.,* 2020). Crude oil contamination could potentially acidify soils, adversely affecting soil fertility and its physical properties (Wang *et al.,* 2013) and thus, diminishing crop plant and other vegetation productivity (Ezeji *et al.,* 2007). John *et al.* (2011) noted that there are observable effects of crude oil on soil physicochemical attributes, plant growth properties and also on the population of heterotrophic 4 and hydrocarbonoclastic microbial populations. Also, the presence of hydrocarbon contamination widens the C: N ratio in such soils, resulting in available nitrogen being immobilized by soil microorganism, thus reducing available nitrogen for plant uptake (John *et al.,* 2016). It has also been reported by Wang *et al.* (2013) that crude oil contamination significantly reduced available phosphorus concentrations in soil, increased organic

carbon concentration and decreased pH remarkably. Thus, as crude oil contamination acidifies ultisol soils, it therefore leads to more deterioration. Agricultural wastes constitute abundant source of both organic and inorganic matter. Empty oil palm fruit bunch (EOPFB) is the largest waste produced during palm oil extraction. Poultry litters on the other hand constitute important soil organic amendments that could offer dependable means of stimulating autochthonal microorganisms to degrade crude oil pollution in soils of the Niger Delta. Cassava (*Manihot esculenta* CRANTZ) is a root tuber plant extensively cultivated as a staple food in the Niger Delta Region of Nigeria. The ability of cassava to withstand difficult growing conditions and long- term storability underground makes it a more resilient crop that could contribute to food security. However, production of cassava in the Niger Delta is masked with many constraints, especially perturbation of land from petroleum hydrocarbon spills and attendant soil nutrient deficiency. Therefore, this study aimed at determining the effect of amending a crude oil polluted soil using oil palm fruit bunch ash (OPFBA) and dried poultry litters (DPL) and evaluated the soil bacterial and physicochemical properties and the growth and tuber yield of cassava (*Manihot esculenta* CRANTZ) grown on the amended soils.

MATERIALS AND METHODS

Site Description of Study Area: An onsite- field experiments were conducted under control and treatment conditions in 2016 and repeated in 2017 cropping seasons at Ikot Ada Udo, a village in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria. Field experiments were carried out on farmlands located in the proximity of corked oil wells, at locations with history of previous oil spill (experienced massive spills in 2007) (Figure 1). According to Udo (2008) Ikot Ada Udo is in the South-Southern part of Nigeria, now politically grouped as the South – South Zone in the Niger Delta Region along the southern coastline (Figure 2 and 3). The climate of the area is humid tropical with heavy rainfall, recording a mean value of 4000 mm. The rainy season is from March to November and the dry season begins in November and ends in February. Harmattan occurs in the months of December and January. Soils in the area are formed on Tertiary Coastal Plain sands (Petters *et al.,* 1989). These soils are deep with loamy sand to sandy loam surface over clay loam to sandy clay subsoil. Because of their sandy nature, they are fragile and highly susceptible to leaching and erosion. They are also acidic and are generally referred to as 'Acid Sands' since they are both acidic and sandy. The vegetation in the area is tropical rain forest. However, in most of the areas the original rain forest has virtually disappeared because of clearing the forest for farming, industries and other types of land use. They are situated within latitudes $04^041'50$ and $04^041'48N$ and longitude $07^041'06E$ and $07^041'03E$. Mean annual temperature varies between $26 – 28^0C$ with relative humidity of $75 – 80\%$.

Fig. 1: Ibibio 1 corked well at Ikot Ada Udo

Experimental Design: The experiments were laid out in a Randomized Complete Block Design (RCBD) with four treatments. The treatments included; Dried Poultry Litters (DPL), Oil Palm Bunch Ash (OPBA), DPL + OPBA and Control (No Manure).

Collection and Processing of Oil Palm Bunch Ash: Empty oil palm fruit bunch were obtained from oil processing mills located at Ikot Adaudo and the surrounding communities. The fresh empty bunches were shredded into small sizes and sun-dried for 5 days to reduce moisture contents after which the samples were oven-dried to dryness. The dried samples were subjected to the process of pyrolysis in a furnace (Gallenkamp-England) at 300°C into char and stored for further use according to Samadhi *et al.*, (2020).

Collection and Processing of Dried Poultry Litters: Litters were sourced from farmers keeping poultry birds in Uyo and Ikot Abasi LGA, Akwa Ibom State. The litters were formed into windrows 45-60 cm height with turning at least once in 5 to 6 days. The high temperature (55°C) generated through microbial actions within the windrow enhances pasteurization that effectively reduced litter pathogen populations and disease risks. Periodic turning ensured adequate ventilation that helped control ammonia volatilization. Sample materials were left exposed to sun radiation for some days to further reduced moisture, while being repeatedly turned. (Osu, *et al.,* 2015)

Fig 2: Akwa Ibom State showing Ikot Abasi Local Government Area (Udo, 2008)

Fig 3: The Location of the corked oil well at Ikot Ada Udo in Ikot Abasi Local Government Area of Akwa Ibom State – Nigeria. SOURCE: (Udo, 2008)

Field Experimentation: The experimental field measuring 42 m x 19 m (798 m^2) was cleared, tilled and demarcated in line with the experimental design into four (4) blocks each comprising of three (3) subplots as replicate plots measuring 3m x 3m (9 m^2) with 1m path separating both the subplots and the blocks. The application was on the basis of weight per area. Five (5) t ha^{-1} of Oil Palm Bunch Ash (OPBA) and 5 t ha^{-1} of Dried Poultry Litters (DPL) were incorporated into soils in two blocks respectively. In the third block, a combination of OPBA (2.5 t ha^{-1}) and DPL (2.5 t ha^{-1}) (OPBA+DPL) were used. All materials used for amendments were thoroughly worked and incorporated into the soil during land preparation. The fourth block served as control and received no amendment treatment. Cassava cuttings; TMS 30572, obtained from Ikot Abasi Zone of Akwa Ibom Agricultural Development Programme (AKADEP) were planted slantingly at an angle of about 45° with the soil in all the subplots accordingly (Udoh, *et al.*, 2005) at a spacing of 1 m x 1 m and allowed a growing period of 36 weeks in each planting season.

Microbiological Analyses: Soil samples from each subplots including the control plots were separately

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weighed (10g) out and suspended in 90 ml of sterile distilled and deionized water in a 250 ml conical flask and thoroughly shaken. These samples were analyzed for total heterotrophic bacteria (THB). The classical 10-fold serial dilution was carried out and 1 ml aliquots of appropriate dilution inoculated by pour plate into Nutrient Agar (NA). Prepared plates were incubated at room temperature (28°C) between 24 and 48 hours before enumeration. Bacteria species were characterized using cultural properties, Gram's reaction and biochemical procedures, and further identified according to the schemes of Holt *et al.* (1994). Densities of the following autotrophic bacterial groups were also determined.

(a) Nitrogen Fixing Bacteria (NFB): The density of nitrogen fixing bacteria from treated soils was enumerated on Bacto Nitrate agar (DIFCO, 1984). Precisely, 21g of Bacto Nitrate Agar was dispensed in 1L distilled water and autoclaved for 15mins at 121°C. After cooling, plates were poured using appropriate volume of aliquot from a serially diluted soil sample and incubated at room temperature (28°C) for 24-48 hours before enumeration.

(b) Sulphate Reducing Bacteria (SRB): The modified Bacto Sulphate API medium (DIFCO) plus agar was adopted for the enumeration and isolation of SRB. One milliliter (1ml) each of the serially diluted soil samples were pour plated and incubated anaerobically at room temperature (28oC) for a period of 48 hours after which colonies were counted and recorded.

(c) Phosphate Solubilizing Bacteria (PSB): The Pikovskaya's agar medium was used for the isolation and enumeration of Phosphate Solubilizing Bacteria. One milliliter of the serially diluted sample was poured plated and incubated at room temperature (28°C). Colonies showing clearing zones on the medium were considered.

Measurement of Growth Parameters: The following growth parameters were measured: plant height (cm), number of nodes per plant, stem girth (cm) and leaf area (cm^2). Growth parameters were randomly measured on four plants per subplot from which the mean was calculated. Plant height was measured from ground level to the highest point of canopy using a tape. The numbers of nodes from the tagged plants were counted. Stem girth was measured using a caliper. To find the leaf area, the length and width of four leaflets of the tagged leaves per plant were measured and the product multiplied by a factor (0.45) as described by Ramanujam and Indira (1978).

Measurement of Yield Parameters: Yield parameters measured included number of tubers per plant, tuber length (cm), tuber girth (cm) and tuber weight (kg^{-1}). The number of tubers per plant was counted, tuber length was measured using a measuring tape, tuber girth was measured using a caliper and tuber weight was measured using a measuring scale.

Determination of Physical and chemical Properties of soil: Soil pH was measured with 1:2.5 soil-water suspension and read using Beckman's glass electrode pH meter, organic carbon was determined by the Walkey Black wet oxidation method (Jackson, 1962), available phosphorus (AP) was measured by Bray P-1 method (Jackson, 1962). The total nitrogen (TN) content was determined by Micro-Kjeldahl method (Jackobson, 1992). Soil particle size distributions were determined by the hydrometer method (Udo and Ogunwale, 1986) using Sodium hexametaphosphate as dispersant. Exchange acidity was determined by titration with 1N KCl (Kramprath, 1967). Exchangeable bases were determined by extraction with 1M NH$_4$OAc (One molar ammonium acetate solution), after which Ca and Mg were determined by EDTA titration method while Sodium and Potassium were determined by photometry method. The effective cation exchange capacity (ECEC) was calculated by the summation method (that is summing up of the exchangeable bases and exchangeable acidity. Base saturation was calculated by dividing total exchangeable bases by ECEC multiplied by 100.

Statistical Analysis: Data collected were computed to determine mean, standard deviation and subjected to analysis of variance (ANOVA). The least significant difference (LSD) was employed to separate significant means, according to the procedure of statistical analysis system (SAS, 1999). Probability limit was set at 95% level of significance ($P<0.05$) as described in Adepoju and Adebanjo (2011).

RESULTS AND DISCUSSION

Population of Autotrophic and heterotrophic bacteria in treated and untreated soils: Results of amendments of hydrocarbon polluted soil using oil palm bunch ash, Dried Poultry Litters singly and in combination in 2016 is presented in Table 1. On the whole, results revealed a generally enhanced population of the various bacterial groups under investigation. NFB population in soils treated with OPBA + DPL, OPBA, and DPL recorded populations in the magnitude 10^5, 10^3, 10^5 CFU/g respectively, while the groups recorded lower populations in the control soils (10^3 CFU/g).

Table 1: Mean Density (cfμ/g) of Autotrophic and Heterotrophic Bacterial groups Isolated from Amended soils in 2016.

Bacterial Group	OPBA+DPL	OPBA	DPL	Mean	SD	Control
Nitrogen fixing bacteria (NFB)	5.1×10^5	3.5×10^3	4.0×10^4	5.5×10^4	0.82×10^4	3.6×10^3
Sulphate reducing bacteria (SRB)	7.5×10^4	5.6×10^3	7.0×10^4	2.5×10^4	0.98×10^4	4.8×10^3
Phosphate solubilizing bacteria (PSB)	3.0×10^3	2.0×10^2	2.4×10^2	2.1×10^3	0.50×10^2	2.5×10^2
Total Heterotrophic bacteria (THB)	3.3×10^7	5.5×10^5	2.8×10^6	3.9×10^6	2.2×10^4	5.3×10^5

Table 2: Mean Density (cfμ/g) of Autotrophic and Heterotrophic Bacterial Groups isolated from Amended soils in 2017.

Bacterial Group	OPBA+DPL	OPBA	DPL	Mean	SD	Control
Nitrogen fixing bacteria (NFB)	3.0×10^5	1.3×10^5	1.2×10^5	1.83×10^5	1.01×10^5	3.7×10^4
Sulphate reducing bacteria (SRB)	2.6×10^5	2.8×10^5	1.4×10^5	2.26×10^5	0.75×10^5	6.7×10^3
Phosphate solubilizing bacteria (PSB)	1.5×10^2	2.1×10^2	2.0×10^2	1.86×10^2	0.32×10^2	4.4×10
Total Heterotrophic bacteria (THB)	1.3×10^7	3.2×10^5	5.6×10^6	3.4×10^6	3.8×10^4	5.8×10^5

Populations of other autotrophic and heterotrophic groups also follow similar trends. Results of the repeated study in 2017 (Table 2) also revealed analogous pattern in which autotrophic bacterial group population in treated soils were higher than those in the control soils. Populations of autotrophic bacteria were observed to be highest in combined OPBA+ DPL treated soils. Dried Poultry Litters (DPL) application (singly) was further confirmed in this study to heightened bacteria population over the application of OPBA.

Plant Growth Parameters: Results of aggregate growth (mean height, number of nodes, stem girth, and leaf area) of test crop from crude oil polluted soil subjected to amendments with OPBA and DPL in the 2016 and 2017 cropping seasons are presented in Figures 4-7. Mean plant heights and number of nodes appreciated between 2016 and 2017. Stem girth and leaf area were observed to record declining values under all treatments. However, application of amendments enhanced growth parameters in plant when compared with control.
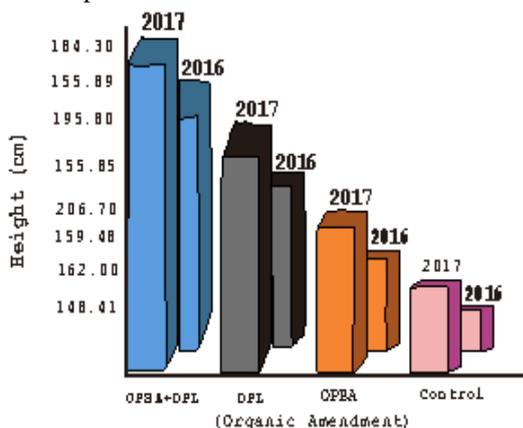

Fig 4. Mean heights of plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017

Plant Yield Parameters: Results of number of tubers, tuber girth, tuber weight, and tuber length are presented in Figures 8-11. Number of tubers increased in 2017 under OPBA+DPL, OPBA, and DPL treatments (Figure 5). Tuber girth appreciated more in

2017 than 2016 under OPBA+DPL exposure, but decreased under DPL amendment (Figure 9). In Figure 10, the weights of tuber showed increased between 2016 and 2017, and the mean length also increased under OPBA+DPL and OPBA influence, but decreased under DPL in 2017 (Figure 11).
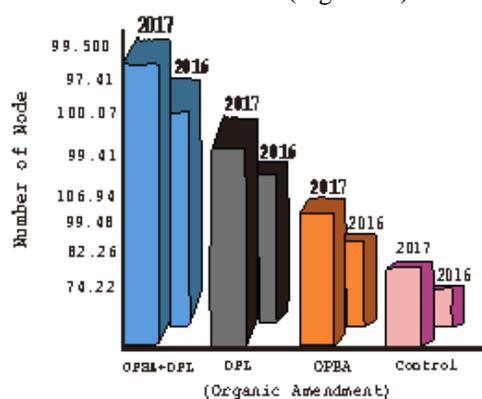

Fig 5. Number of nodes per plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017
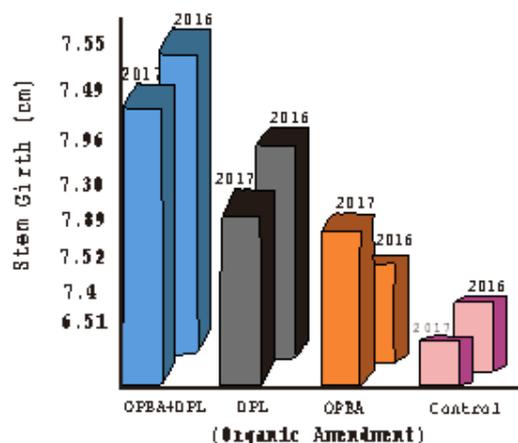

Fig 6. Strength of plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017

Physicochemical Properties of Soils before Amendments: Results of soil properties of the sites conducted in 2016 and 2017 are presented in Table 3. Sand fraction dominated the particle size distribution of the soil with the texture being generally loamy.
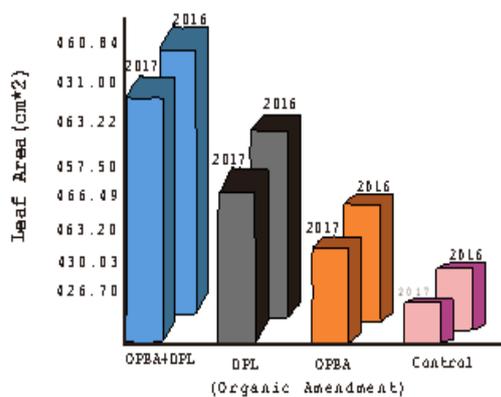
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Fig 7. Leaf area of plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017
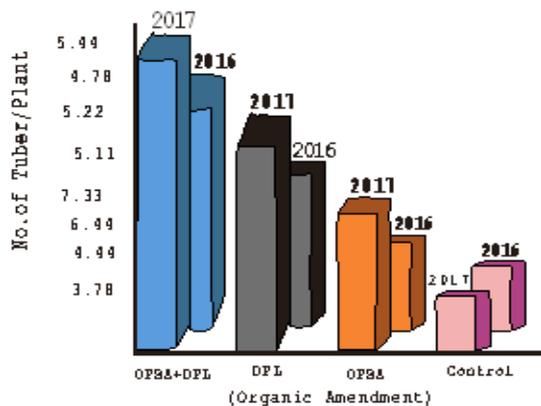

Fig 8. Number of tubers per plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017
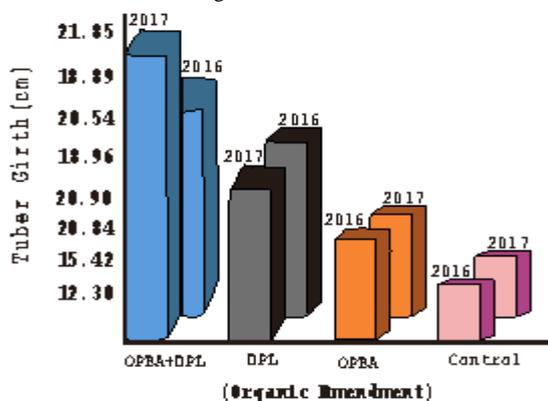

Fig 9. Number of tubers girth from plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017

Ca, followed in the order by exchange acidity, Mg and Na. Base saturation was high in both years (80% and 71.33% respectively). Total petroleum hydrocarbon was 156.45mgkg^{-1}in 2016 and 127.93 mgkg^{-1}in 2017.
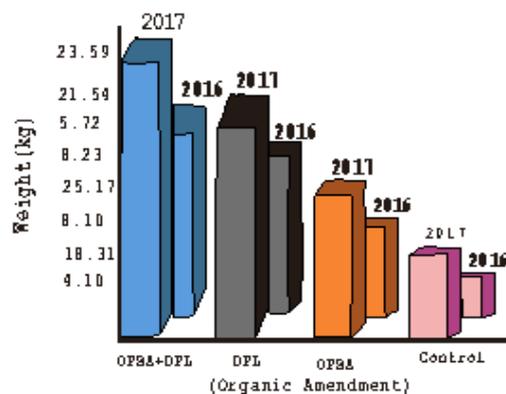

Fig 10. Weight of tubers girth from plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017
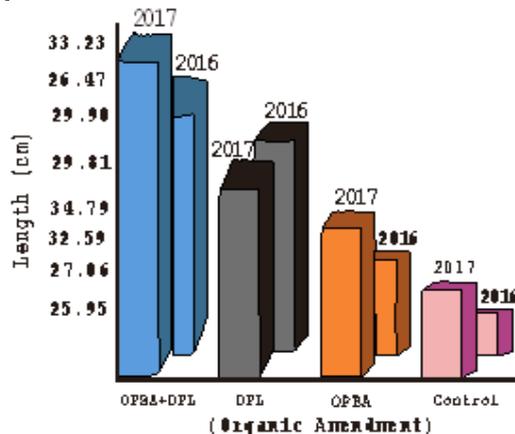

Fig 11. Mean Length of tubers girth from plants grown in crude oil polluted soil amended with organic manure in 2016 and 2017

Table 3: Some Physical and Chemical Properties of Unamended soils of the Study Area

Soil Property	Units	2016	2017
Sand	(g kg^{-1})	872.00	843.50
Silt	(g kg^{-1})	36.98	40.60
Clay	(g kg^{-1})	91.02	115.90
Texture	-	loamy sand	loamy sand
pH	-	5.08	6.80
EC	(dSm^{-1})	0.43	0.50
OC	(g kg^{-1})	30.67	32.87
TN	(g kg^{-1})	0.63	0.69
AP	(mg kg^{-1})	13.23	15.02
Ca	(cmol kg^{-1})	3.23	2.21
Mg	(cmol kg^{-1})	1.05	1.36
K	(cmol kg^{-1})	0.53	0.37
Na	(cmol kg^{-1})	0.11	0.14
EA	(cmol kg^{-1})	1.23	1.64
ECEC	(cmol kg^{-1})	6.15	5.72
BS	(%)	80.00	71.33
TPH	(mgkg^{-1})	156.45	127.93

EC – Electrical Conductivity, OC – Organic Carbon, TN – Total Nitrogen, AP – Available P, EA – Exchange Acidity, BS – Base Saturation, TPH – Total Petroleum Hydrocarbon

In both years, the pHs of the soils (5.08 and 5.60 respectively) were acidic, organic carbon contents were high, generally >30 g kg^{-1} just as available P were moderate at 13.23mg/kg^{-1} and 15.02mg/kg^{-1} in 2016 and 2017 respectively. Extremely low TN values of 0.63g/kg^{-1} and 0.69g/kg^{-1} were recorded in 2016 and 2017 respectively. Based on the classification provided by Claude *et al.,* (2012), effective cation exchange capacity were low in both years (6.15 and 5.72 cmol kg^{-1}, respectively) and was dominated by

Properties of Amendments (OPBA, DPL and OPBA+DPL): Chemical compositions of amendment materials used in the study are presented in Table 4. Analyses of the chemical properties of amendments used in this study showed the following; pH, 6.88 and 6.97 for DPL in 206 and 2017 respectively. OPBA (8.98 and 9.24), and 8.12 and 8.19 for OPBA+DPL in 2016 and 2017 respectively. Organic carbon (OC) content was highest in DPL ($302.30 g/kg^{-1}$ and $202.54 g/kg^{-1}$) in 2016 and 2017 respectively. In 2016,

OC content in OPBA and OPBA+DPL were $45.00 g/kg^{-1}$ and $201.70 g/kg^{-1}$ respectively. Dried Poultry Litters sample materials had enhanced N, P, and Ca content in both 2016 and 2017 when compared to OPBA and combined OPBA and DPL. However, in 2017 magnesium ($1167.32 mg/kg^{-1}$) and potassium ($4537.67 mg/kg^{-1}$) content increased in value in OPBA, while content of Mg further intensified in OPBA + DPL ($2354.83 mg/kg^{-1}$).

Table 4: Chemical Composition of DPL, OPBA and combined OPBA+DPL used for the Study in 2016 and 2017.

Parameter	DPL	OPBA	OPBA +DPL	DPL	OPBA	OPBA +DPL
	2016 Cropping Season			**2017 Cropping Season**		
pH	6.88	8.98	8.12	6.97	9.24	8.19
EC (dS m^{-1})	4.26	6.01	5.44	3.56	5.67	4.54
OC (g kg^{-1})	302.30	45.00	201.70	202.54	67.26	189.56
N (g kg^{-1})	19.79	14.69	16.53	21.67	12.93	14.78
C/N Ratio	15.28	0.87	12.20	9.35	12.94	12.83
P(mg kg^{-1})	6300.50	350.68	4300.62	5639.84	329.98	4170.43
Ca (mg kg^{-1})	8540.45	7440.56	8223.42	7865.21	5698.78	5983.01
Mg (mg kg^{-1})	577.37	489.32	645.82	875.43	1167.32	2354.83
K (mg kg^{-1})	946.47	383.68	2657.28	2378.34	4537.67	3257.65
Na (mg kg^{-1})	456.97	565.24	1891.19	1573.21	1383.21	163.98

DPL – Dried Poultry Litters; OPBA – Oil Palm Bunch Ash; EC – Electrical Conductivity

Effect of Organic Manure on Some Physicochemical Properties of Crude Oil polluted soil: Mean results of some chemical and physical properties of crude oil polluted soil after amendment with organic manure is presented in Table 5. It is apparent from this results that addition of organic manure to crude oil polluted soil fructifies the soil by increasing diminished or lost properties. It is observed that concentrations of the following; organic carbon, Available Phosphorus, Calcium, Magnesium, Sodium, and Potassium were remarkably increased when organic manure were

added to the soil. Total petroleum hydrocarbon (the pollutants) concentrations also significantly reduced in the soil after addition of organic amendments. The addition of DPL increased in the organic carbon of soil from $24.03 g/kg^{-1}$ to $45.9 g/kg^{-1}$ and $34.9 g/kg^{-1}$ in the 2016 and 2017 cropping seasons. Also amendment with OPBA raised the available phosphorus from to $334.10 mg/kg^{-1}$ and $333.58 mg/kg^{-1}$ in 2016 and 2017 respectively. The concentration of K was also increased to $473 cmol/kg^{-p1}$ and $516 cmol/kg^{-1}$ in the years under consideration.

Table 5: Mean Results of some Physical and Chemical Properties of Crude Oil Polluted soil as Affected by Organic Amendment during 2016 and 2017 Cropping Seasons

Organic Manure	pH	OC	Total N	Avail. P	Ca	Mg	Na	K	TPH
		← (gkg^{-1}) →		(mg kg^{-1})	← (cmolkg^{-1}) →				(mg kg^{-1})
	2016 cropping season								
OPBA	7.51	38.2	5.51	334.10	6784.19	490	655	473	280.76
DPL	6.91	45.9	15.7	6333.79	7660.23	620	575	578	211.14
OPBA+DPL	6.31	39.1	22.7	6434.38	8770.17	652	684	652	116.87
Control	5.79	13.0	1.41	123.06	12.14	301	284	184	329.78
	2017 cropping season								
OPBA	7.88	26.90	6.86	333.58	7603.42	522.	511	516	18.20
DPL	6.94	34.97	16.1	422.67	8323.98	692.	620	592	17.14
OPBA+DPL	6.53	31.37	21.0	528.21	8793.56	752.	721	621	16.75
Control	6.71	14.03	0.77	120.20	22.92	21.8	18	11	

OC – Organic Carbon, EA – Exchangeable Acidity, ECEC – Effective Cation Exchange Capacity, BS – Base Saturation, TPH – Total Petroleum Hydrocarbon, LV – Local Variety, DPL – Dried Poultry Litters, OPBA – Oil Palm Bunch Ash, LSD – Least Significant Difference

Petroleum hydrocarbon adversely affects soil functions and eco-services by altering natural balance that exists between physical, chemical, and biological properties of the soil. These changes have profound

effects on soil properties especially on fertility, microbial community structure, and plant communities. Crude oil impacted soils require remediation and restoration to its natural conditions

and is necessary in order for such soils to support further plant growth and other ecosystem services. Amendments with materials of organic origin has proved to be economical, efficient, eco-friendly, and capable of additionally solving solid waste management issues. Organic manure used for this study was rich sources of plant nutrients such as organic carbon, nitrogen, phosphate as well as basic cations (Ca, Mg, K and Na). The chemical compositions of the organic manures used were observed to significantly improve the properties of crude oil polluted soil in both years. These findings corroborate the work of Bot and Benites (2005), who reported that with addition of organic matter, polluted soils recovers its remediating capacity. It was observed that OPBA and DPL addition increased soil pH because of the high potassium and calcium contents in them. The k and Ca in the samples replaced the H^+ and Al^{3+} in the exchange sites, thus increasing the soil pH. Awodun *et al.* (2007) also found ash treatments to have liming effect on soil by increasing soil pH. High nitrogen content in DPL favored luxuriant growth of crop plants, as it eventually returned organic N to the soil. Rahman (2014) compared poultry manure with other organic manure and found poultry manure to be efficient in increasing carbon and nitrogen contents in soils compared to other organic manure. Furthermore, poultry manure is preferred amongst other animal wastes because of its high concentration of macro-nutrients (Warman, 1986). In crude oil polluted soils, these nutrients improve C: N ratio and N as a nutrient, with attendant effects on both increase in microbial populations and decrease in hydrocarbon contents. The ratio has direct impact on residue decomposition and N cycling in soils. The presence of organic substrate allows microorganisms to increase their metabolic activity in the production of extracellular enzymes and biosurfactants directed towards the degradation of crude oil (Rocchetti *et al.,* 2011). The lowered concentration of TPH in soils in 2017 compared with 2016 and the control soil could be attributed to improved C: N ratio provided by the amendments. Application of OPBA, DPL and OPBA+DPL significantly increased plant heights, number of nodes per plant, stem girth and leaf area when compared with those of control. There was a noticeable increase in primary growth but reduction in secondary growth possibly due to anatomical plasticity in response to crude oil. However, the generally improved performance of the test crops maybe attributed to the role of organic manure in improving soil functions that allowed autotrophic and heterotrophic bacterial proliferation, and physicochemical properties alteration (Cogger, 2005; Zhang, 1994; Thomas *et al.,* 1996; Curtis and Claassen, 2009; Osu *et al.,* 2020 and

Osu *et al.,* 2021) resulting in increased crude oil degradation in soil, thereby providing an environment for better growth than the control. The combination of DPL and OPBA (OPBA+DPL) was more effective than other sets of amendment because in the combination, OPBA may have potentiated the effect of DPL (Gbosidom and Teme, 2015) probably due to the high content of plant nutrients in both oil palm bunch ash and dried poultry litters as confirmed in this study. Nilnoree *et al.,* (2015) had reported increased performance of cassava crop due to the high amounts of plant nutrients contained in poultry manure, while Ojeniyi *et al.,* (2009) reported increased performance of the crop as a result of the application of oil palm bunch ash. In terms of single applications, DPL alone gave better growth than OPBA. For all parameters evaluated, the combination of OPBA and DPL i.e. (OPBA+DPL) which produced the highest growth in cassava also gave a proportionate increase in yield (more outstandingly in 2017 growing season) compared to cassava that received other organic manures. This is because of the nutrients adding potentials of both OPBA and DPL, which subsequently provided the best conditions for improved yield. The consistently least values of yield parameters in Control compared to treatments is indicative of the fact that crude oil polluted soils can be ameliorated to give better yield of cassava by the addition of organic manure such as OPBA and DPL.

Conclusion: This study revealed that the presence of crude oil in agricultural soil adversely inhibits cassava growth and development as evidenced in the control soil experiments, whereas, oil palm bunch ash in combination with dried poultry litters can serve a good option in mitigating toxicity of crude oil pollution in soils of the Niger Delta by improving rate of petroleum hydrocarbon degradation. The results also showed that the amendments supplied nutrients to indigenous populations of autotrophic and heterotrophic bacteria to heighten their metabolic machinery towards effective scavenging of the oil pollutants in the soil. These results confirm the efficacy of biostimulation in the removal of crude oil contaminants from soils.

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