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ENHANCING PHYTOREMEDIATION POTENTIAL OF *Andropogon tectorum* (Schumach & Thonn) IN PETROLEUM HYDROCARBON CONTAMINATED SOIL USING CASSAVA PEEL

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ABSTRACT

This study investigated the effects of cassava peel amendment on phytodegradation of petroleum hydrocarbon polluted site grown with Andropogon tectorum. The study was carried out in Botem community in Tai Local Government Area of Rivers State. The experiment comprised four- treatment set-up; T_1 (Crude oil polluted soil + Andropogon tectorum), T_2 (Crude oil polluted soil + Andropogon tectorum + 500 g cassava peel), T_3 (Crude oil polluted soil + Andropogon tectorum + 1000 g cassava peel) and the control T_4 (Crude oil polluted soil alone). Soil/ plant hydrocarbon and soil physicochemical were done at 2 month interval after amendment and planting. Results showed higher reductions of total petroleum hydrocarbon (TPH) and total hydrocarbon content (THC) in treated soil (T_1, T_2 and T_3) than control. Highest percentage reduction in TPH (94.23 %) and THC (97.07 %) were obtained in soil phytoremediated with A. tectorum and 500 g cassava peel amendment while the control recorded the least (TPH: 14.76% and THC: 32.90 %). Alteration in the physico-chemical parameters with increase in soil pH and nitrogen was observed in phytoremediated soil with amendment. Results also showed accumulation of hydrocarbon in plants in all the treatments. Addition of cassava peel amendment (T_2 and T_3) increased TPH and THC accumulation in the test plant than the one without amendment T_1 (Andropogon tectorum only).This shows that cassava peel has the potential to enhance the rate of phytoremediation of hydrocarbon in Andropogon tectorum and should be considered in remediation of contaminated sites.

Keywords: phytoremediation, cassava peel, *Andropogon tectorum*, pollution, crude oil, soil.
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INTRODUCTION

Pollution is a problem and a common hazard in the Niger Delta Region; due largely to crude Oil exploration and exploitation in the area. Man's activities and inventions in other to raise the standard of living through the exploitation of natural resources has obviously led to the release of toxic substances called pollutants, which lead to interference with the normal functioning of the ecosystem. Many pollutants are phytotoxic and their spillage can have adverse effects on valuable plant communities. Most agricultural lands have been contaminated during these spills and it has become a serious global problem (*Ji et al*., 2011). According to Steiner (2008), oil spills in communities in the Niger Delta have been extensive, difficult to assess and often under reported. In Nigeria environment; big oil spills are no longer news in the vast tropical lands of the Niger Delta.

Petroleum hydrocarbon pollution can occur on land or in water bodies and it is currently on the increase. This is displeasing due to its negative consequences. Crude oil in soil alters soil physico-chemical properties such as aeration, pH, capillarity, organic/ inorganic nutrient contents and biota (Kayode *et al*., 2009, Gighi *et al*., 2012). These soil properties contribute to the sustainability of plants (Verma and Agarwal, 2007). As a result, many food crops are at considerable risk, which will invariably have drastic effects on crop production and economic livelihood of the local communities affected by the pollution (Inoni *et al*., 2006). Due to this ugly trend of oil spill, every step must be taken to avert this incidence or restore the affected habitat.

Methods for removing, reducing or mitigating toxic substances introduced into soil need to be used. Traditional methods of soil remediation (such as liming, washing, leaching, turning and deep plowing) are usually energy consuming and require expensive machinery that often causes secondary pollution (Park *et al*., 2011). With the high costs of site remediation, it is important that efforts continue to develop and refine innovative and low cost methods for cleaning the environment. Hence, the use of phytoremediation comes into play. Phytoremediation exploits the abilities of green plants for the uptake and degradation of pollutants. This practice involves the use of green plants and other agronomic practices to reduce, immobilize and detoxify contaminants (USEPA, 2000). In phytoremediation, plants play the role of adsorption, accumulation and volatilization of compounds, the enhancement of soil rhizosphere activity, or degradation of organic pollutants (phytodegradation) (Ali *et al*., 2013).

The exploitation of soil amendments in phytoremediation aims at enhancing the medium to be remediated, the type of plant used, and also the physical properties of the contaminant. However, there is evidence that application of both organic (compost, coal fly ash, sugar foams and biosolids) and in-organic (lime and zero valent iron grid) amendments in the contaminated sites facilitates plant biomass production, self-propagation of introduced plant material, plant survival and productivity for a long-term period, as well as increases plant diversity (Mench *et al*., 2010). Organic amendments (biochelators) can increase bioavailability and mobility of soil pollutants, mainly metals and metalloids, thus increasing phytoextraction efficiency. However, in order to improve plant growth characteristics (i.e., biomass production), effects exerted by soil amendments on plants should be evaluated. The most frequently reported is the addition of agro and industrial wastes, biochar and organic matter, including materials containing humic substance. Depending on the needs, both inorganic and organic amendments in

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phytoremediation are to immobilize pollutants or to increase their uptake and translocation to harvestable plant biomass. The mode of action and effectiveness of numerous amendments in soil remediation is quite well recognized.

This study was carried out to evaluate the effect of cassava peel amendment on phytodegradation of hydrocarbons in soil with *Andropogon tectorum*.

MATERIALS AND METHODS

Description of experimental site

The experimental site was a crude oil polluted land in Botem community in Tai Local Government Area of Rivers state, situated in the Niger Delta area of Nigeria. The polluted site is located on the GPS coordinates N 4°43□ 29.5608□□' , E 7°16□ 8.382□' . It is an oil impacted site from a broken oil pipe owned by Shell BP over a year before the study was done.

Sources of materials

Dried and ground cassava peel (organic amendment) used in the study was collected from local farmers who removed these peels during Garri processing. The peel collected was sun- dried for two weeks and ground. The chemical composition was analyzed thus: pH 5.3 phosphorus 0.12 mg/kg Nirtogen.1.686%, potassium 2459.5 mg/kg, sodium 636.52 mg/kg, magnesium409.38 mg/kg calcium 193.77 mg/kg. Seedlings of *Andropogon tectorum* used for phytoremediation were obtained from the wild (unpolluted sites) in Botem community.

Experimental design

A Latin Square Design (LSD) comprising four (4) treatments with four replications (4) was used for the experiment. The four treatments were as follows:

T_1 = polluted soil + *Andropogon tectorum*

T_2 = polluted soil phytoremediated with *A. tectorum* and amended with 500 g cassava peel powder

. T_3 = polluted soil phytoremediated with *A. tectorum* and amended with1000 g cassava peel powder

T_4 = polluted soil without any phytoremediation and amendment (control)

The polluted site was subdivided into four (4) subplots of 1m x 1m dimensions with intervals of 0.5m in between plots. Each subplot was replicated four (4) times.

T_1	T_2	T_3	T_4
T_2	T_3	T_4	T_1
T_3	T_4	T_1	T_2
T_4	T_1	T_2	T_3

Fig. 1 Experimental design

PLANTING

The phytoremediation site was tilled (scarification) in preparation for planting. Dried grounded cassava peel (500 g and 1000 g) was added to soil in T_2 and T_3 respectively and allowed to stand for one week. These subplots were tilled with shovel before planting was done on them.

Young seedlings of *Andropogon tectorum* of same size and vigor were collected from the wild (unpolluted site) and were transplanted into their respective plots (T_1, T_2 and T_3). Treatment T_4 was without plant. A minimum of thirty (30) seedlings of each plant were planted per subplot.

Soil collection and Analysis

Pre-Treatment Collection: Before planting was done, samples of soil were collected from all subplots in the polluted site. The samples were collected from the soil at a depth of 0 – 15 cm using a soil auger. Soil samples collected from different subplots were mixed homogenously to form a composite sample. This was put into a perforated nylon bag and then labeled.

Post-Treatment Collection: This was done at two month interval. Plant samples and Soil samples around the rhizosphere (root zone) of the plants in the different treatment plots were taken. Soil samples were also taken from the untouched subplots of the polluted sites (polluted alone).

Analysis of Samples: The samples (soil and plant) were taken to the laboratory for analysis. Soil chemical properties examined are: Potassium (K), Phosphorus (P), Total Organic Carbon (TOC), Total Nitrogen (N), Total Hydrocarbon Content (THC), Total Petroleum Hydrocarbons (TPH), Soil pH and electrical conductivity.

Determination of measured parameters

The electrical conductivity and pH of the soil were determined electronically using a glass electrode pH metre (PHS. 25 Model) and conductivity metre (Labtech Model), respectively. TNRCC Tx Method 1005, (1997) was used to determine the total petroleum hydrocarbon in soil and plant. The API-RP45 Colorimetric method used by Aigberua *et al.* (2016) was used to determine the Total Hydrocarbon Content (THC) of soil and plant sample. Black Method (Black, 1965) was used to determine Total Organic Carbon (TOC). Total Organic matter content of soil was determined by calculation, using the formula outlined by Combs and Nathan (2011). Kjeldahl Method (Stewarte *et al*., 1974) was used to determine total nitrogen of the soil. Black Method (Black, 1965) was used to determine potassium in the soil. Bray No.1 Method (Bray and Kurtz, 1945) was used to determine available phosphorus in soil.

Data Analyses

Statistical evaluation such as means, standard error means (SEM), two- way ANOVA and Least significant difference (LSD) were determined using Duncan Multiple Range Test (DMRT), 2018 version. Results were presented as mean ± SD using histograms.

RESULTS

Phytoremediation of the crude oil spill impacted site causes changes in soil properties such as total hydrocarbon content, total organic carbon, Total organic matter, nitrogen, total phosphorus and potassium of the soil. Amendment of phytoremediated contaminated soil with cassava peel is shown to cause significant reduction in the soil total petroleum hydrocarbon (TPH) and total hydrocarbon content (THC) of the different treatment options (Fig.2) and (Fig. 3) respectively.

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Significant reduction in Total Petroleum Hydrocarbon (TPH) in all the treatments (Fig.2) was observed. Treatment T_2 (polluted soil + *A. tectorum* + 500 g cassava peel) recorded highest percentage reduction (89.95 % and 94.23 %) and the least (1.34 % and 14.76%) was obtained in the control (T_4) at 2 month and 4 month respectively. There was significant difference in TPH reduction between other treatments and treatment T_4 at both month observed, P = 0.05. However, within treatments at 2 month there was significant difference between treatment T_2 and other treatments. At 4 month, there was also significant difference between treatment T_2 and other treatments except T_1 (polluted soil + *A. tectorum*). The significant difference was at P = 0.05. Results also showed reduction in Total Hydrocarbon Content (THC) of soil (Fig.3), THC reduced in all the treatments with treatment T_2 having the highest percentage reduction (94.70 % and 97.07 %) while treatment T_4 (the control) recorded the least percentage reduction (24.75 % and 32.90 %) at 2 month and 4 month respectively. There was significant difference between treatments; T_1, T_2, T_3 and treatment T_4 at both month. Results also showed significant difference between treatment T_2 and treatments; T_1, T_3 at 2 month and 4 month, P = 0.05 respectively.

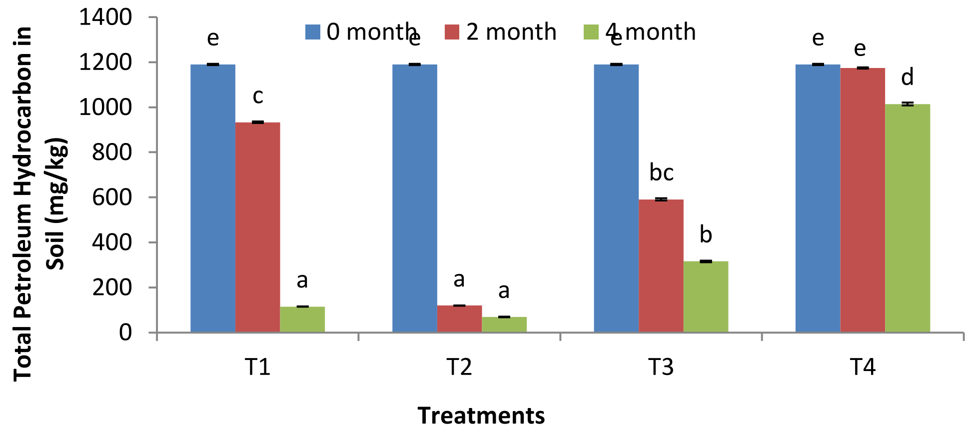

Fig.2: Effects of Treatments on mean total petroleum hydrocarbon in soil

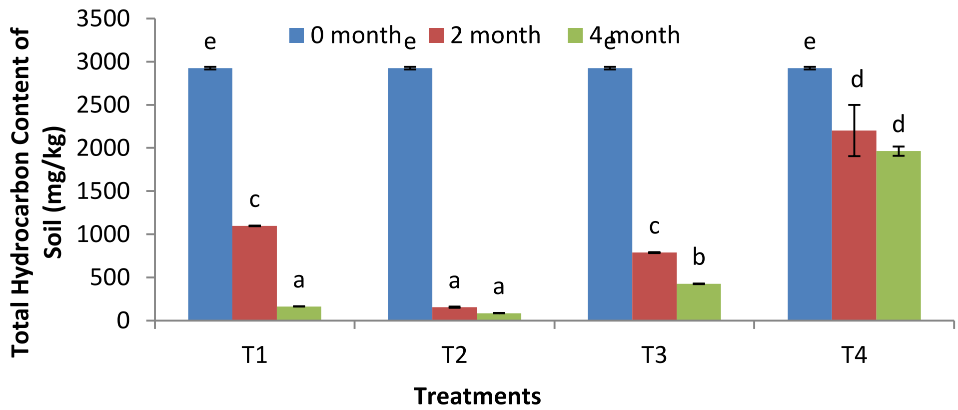

Fig. 3: Effects of treatments on total hydrocarbon content of Soil

Fig. 4 and 5 show effects of the different phytoremediation treatments on soil pH and electrical conductivity. Soil pH increased in all the treatments (Fig. 4). Least increase was observed in treatment T_4 (polluted soil alone) at both months. At 2 month, there was significant difference between treatment T_3 and treatments T_2, T_4. At 4 month, there was significant difference between all the treatments. The significant difference is at P = 0.05. Result for electrical conductivity is presented in Fig. 5. At 2 months, increase in electrical conductivity was recorded in treatments; T_2, T_3 while treatment T_1 and T_4 recorded decrease in soil electrical conductivity. However, at 2 months highest electrical conductivity of soil was recorded in treatment T_3 (polluted soil + *A. tectorum* + 1000 g cassava peel) and least in treatment T_1 (polluted soil + *A. tectorum*). Results showed significant difference between treatments T_3, T_2 and other treatments respectively. There was no significant difference between treatment T_1 and treatment T_4. At 4 months, there was significant difference between treatment T_1 and treatments T_2, T_3, T_4. There was also significant difference between treatment T_4 and treatments T_2, T_3, P = 0.05. There was no significant difference between treatments T_2 and T_3.

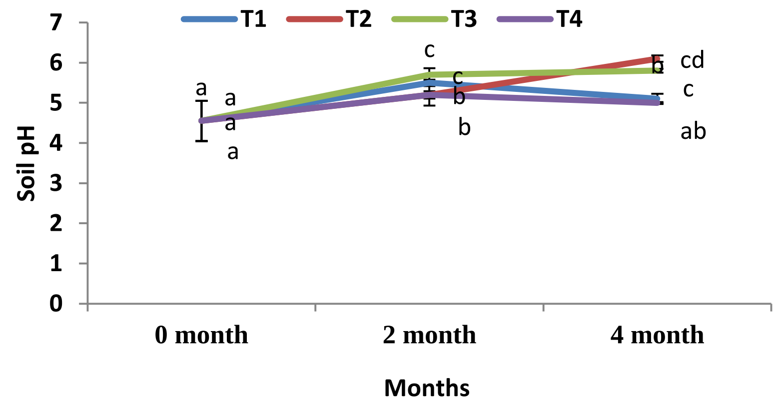

Fig. 4:Effects of Treatments on mean Soil pH

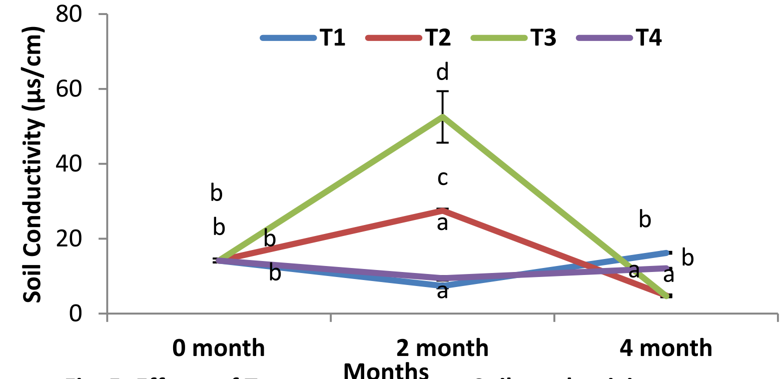

Fig. 5: Effects of Treaments on mean Soil conductivity

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Fig. 6 showed that phytoremediation of the contaminated soil with the different quantity of cassava peel amendment options affected the soil nitrogen.

Increase in Total Nitrogen of soil was obtained in treatments T_2 and T_3 at 4 months. There was significant difference between treatment T_1 and treatments T_2, T_4. There was also significant difference in nitrogen between treatments T_2, treatment T_3 and other treatments respectively.

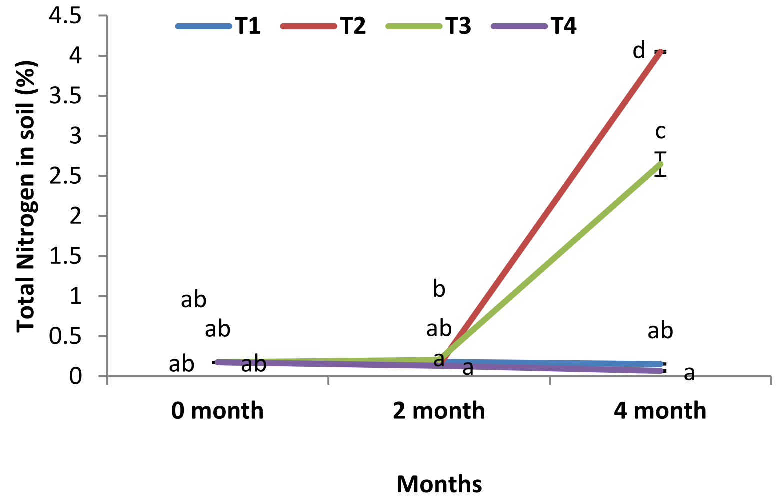

Fig. 6: Effects of Treatments on mean total Nitrogen in Soil

Results of TOM (Fig. 7) and TOC (Fig. 8) followed the same trend. Total organic matter in soil (TOM) increased in the amended treatments (T_3 and T_2) at 2 and 4 months respectively. Decrease in TOM was observed in T_1 (polluted soil + *A. tectorum*) and T_4 (polluted soil alone) at both months. There was significant difference in TOM between treatment T_3 and other treatments at 2 months ($P = 0.05$). At 4 months, there was significant difference between all the treatments Total organic carbon increase in treatments T_2 and T_3 (amended treatments) while polluted soil + *A. tectorum* (T_1) and polluted soil alone (T_4) recorded decrease in total organic matter of soil. There was significant difference in TOC between treatments T_1, T_3 and treatment T_4 at 2 months ($P = 0.05$). There was no significant difference between treatment T_2 and T_4. At 4 month, there was significant difference between the treatments, ($P = 0.05$).

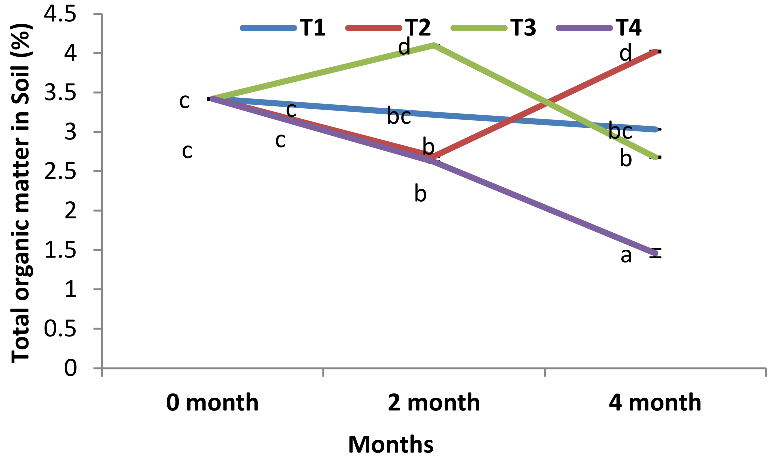

Fig. 7: Effects of Treatments on mean total organic matter in Soil

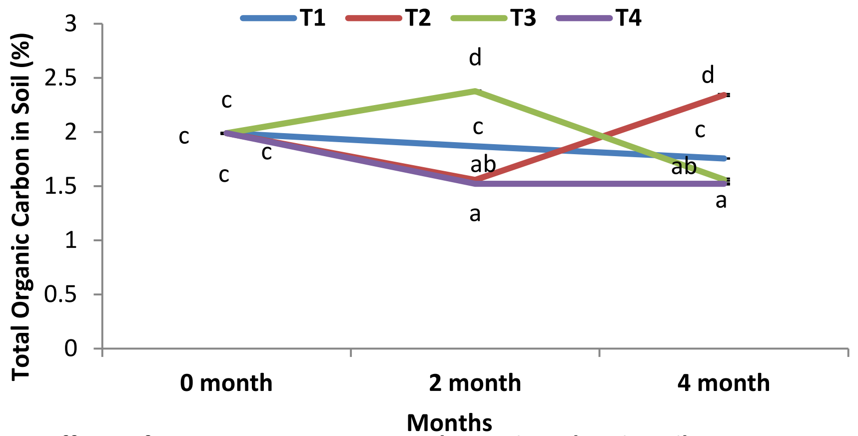

Fig. 8: Effects of Treatments on mean total organic carbon in Soil

Fluctuation in total potassium of soil was observed in all the treatments (Fig.9). At 2 months, highest potassium in soil was recorded in treatment T_4 (polluted soil alone) while the least was obtained in treatment T_2 (polluted soil + *A. tectorum* + 500 g cassava peel). There was significant difference in potassium between the treatments at both months observed, $P = 0.05$.

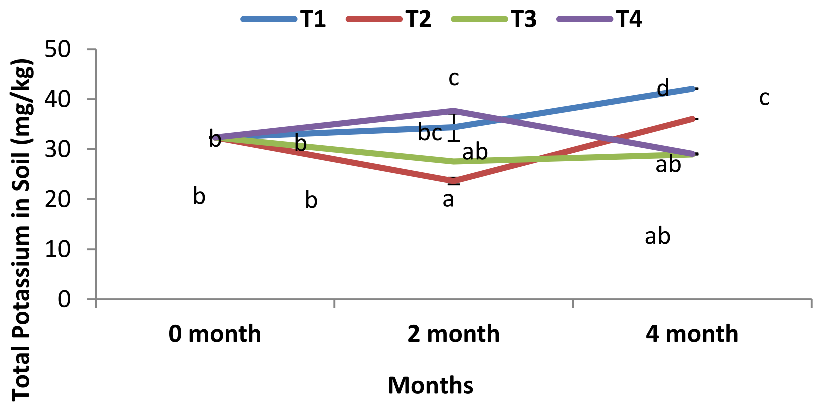

Fig. 9: Effects of Treatments on mean total Potassium in Soil

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Increase in soil phosphorus was observed in all the treatment at 2 month and 4 month except in treatment T_1 at 4 months where decrease was observed compared to that of 0 month and 2 months (Fig. 10). There was significant difference in phosphorus in soil between treatment T_4 and treatments; T_1, T_2, T_3 at 2 months, (P = 0.05). At 4 months, there was significant difference between treatment T_4 and treatments; T_2, T_3 (P = 0.05). There was no significant difference between treatment T_2 and T_3 at 2 and 4 months respectively.

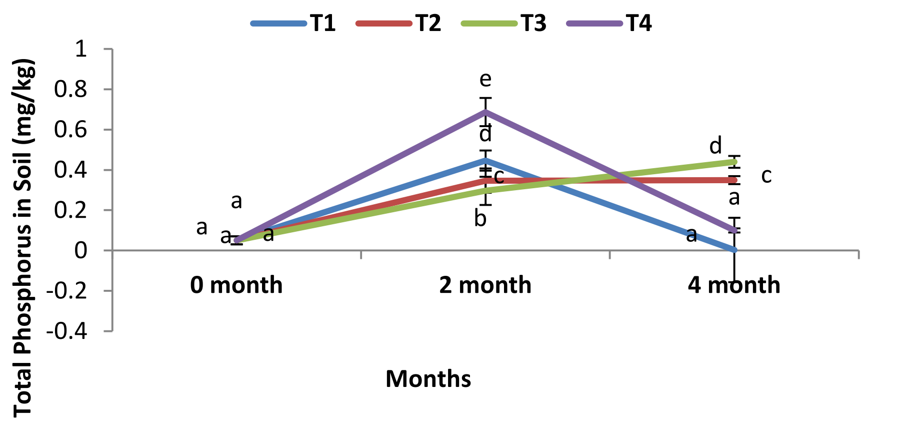

Fig.10: Effects of Treatments on mean total Phosphorus in Soil

Total petroleum hydrocarbon (TPH) was accumulated in plants in all the treatments (Table1). Amended treatments (T_1 and T_2) recorded higher TPH accumulation than phytoremediated treatment alone (T_1) at both months. There was significant difference in TPH accumulation by plant between the treatments at 2 month and 4 month, P = 0.05.

Result also showed accumulation of Total hydrocarbon content in plant (Table 1). At 2 months, highest THC in plant was obtained in treatment T_3 (polluted soil + *A. tectorum* + 1000 g cassava peel) while T_1 (polluted soil + *A. tectorum*) recorded the least THC. There was significant difference in THC of plant between the treatments. At 4 months treatment T_2 (polluted soil + *A. tectorum* + 500 g cassava peel) recorded highest THC in plant. There was significant difference between T_2 and treatment T_1. The significant difference as at P = 0.05.

Table 1: Hydrocarbon accumulation in Plants

Treatments	Total petroleum hydrocarbon(TPH) in plant (mg/kg)		Total hydrocarbon(THC) in plant (mg/kg)	
	2 month	4 month	2 month	4 month
T_1	0.56 ± 0.05^a	0.97 ± 0.03^b	1.72 ± 0.16^a	2.58 ± 0.11^b
T_2	2.99 ± 0.02^d	3.21 ± 0.01^e	7.52 ± 0.91^d	9.89 ± 0.23^e
T_3	1.54 ± 0.06^c	2.66 ± 0.03^d	3.64 ± 1.25^c	7.83 ± 0.18^d

DISCUSSION

The negative effect of crude oil pollution on the environment is a well known issue in our society and as such many environmental organizations in a bid to reduce these effects have developed clean up strategies for petroleum hydrocarbon contaminated soil. Phytoremediation has proved to be an effective technique in remediation of contaminated soil.

The reduction in total petroleum hydrocarbon (TPH) and total hydrocarbon content of soil (THC) was observed in phytoremediated soil with *A. tectorum*. *Andropogon tectorum* showed tolerance to hydrocarbon contamination of soil in this study. Hydrocarbon contamination of soil could not disturb the growth of the plant species. This shows that *A. tectorum* has the potential for phytoremediation of hydrocarbon in soil (McClutchen and Schnoor, 2003; Merkl *et al*. 2005; Olajuyigbe and Aruwajoye, 2014). However, enhancing it with cassava peel (treatments T_2 and T_3) showed greater reduction in TPH and THC. This shows that organic amendments such as cassava peel have the ability to accelerate phytodegradation of crude oil contaminant ion by improving soil properties and pollutant mobility in soil (Mench *et al*., 2010). Crude oil pollution can cause changes in soil chemical properties by either increasing or decreasing them (Benson *et al*., 2016; Edokpolor *et al*., 2019). There was change in the pH and electrical conductivity of soil between the amended and un-amended soil phytoremediated soil. Increased pH (decrease acidity) and electrical conductivity of soil observed in cassava peel amended treatments (T_2 and T_3) is an indication that the addition of cassava peel to the crude oil contaminated soil reduced acidity of soil through improved nutrient (humus) availability thus providing a pH range favourable for soil microorganisms for biodegradation of contaminants (Esin and Ayten, 2011; Angin *et al*., 2013). High soil pH has been associated with high humus content of soil (Opala *et al*., 2012). It is obvious that the cassava peel amendment helped in the release of dissolved solutes, hence, led to increase in electrical conductivity observed (Waafa *et al*., 2016). Results showed an increase in Nitrogen content of soil in cassava peel amendment plot planted with the test plant (*A. tectorum*) as compared to non amended soil. Similar trend was observed in total organic matter and total organic carbon. Organic matter has been known to contain nitrogen as a principal component (Kamolchanok *et al*., 2012) hence the high nitrogen content in the soil with amendment is an affirmation of that fact. This high nitrogen content coupled with a favouarable pH provides a better condition for microorganisms found within the rhizophere to thrive thus enhancing the biodegradation process through the plant – microbial interaction (Glick, 2010; Divya and Deepak, 2011). This is justifiable since nutrient deficiency is a major factor limiting biodegradation of petroleum hydrocarbon compounds (Tanee and Kinako, 2008; Turgay *et al*., 2010). It is also possible that the increased microbial population due to high nutrient content fixed nitrogen in the soil thus contributing to the increase in the soil nitrogen (Odokuma and Ibor, 2002; Das and Chandran, 2011). In addition soil

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microorganisms may utilize the carbon as energy source for degradation of crude oil. This is in line with the report of Lee *et al*. (1995) (Odokuma and Ibor, 2002; Jones *et al*., 2018) that organic manures have effects in stimulating crude oil breakdown by increasing the total heterotrophic microbial growth and activity. Mbah *et al*. (2009) and Nwandinigwe and Onyeidu, (2012) observed similar results. The increase in organic carbon and organic matter content of the soil may also be attributed to the decomposition of the amendment agents and / or hydrocarbons by microbial actions. Crude oil has been known to contain high amount of carbon (Speight, 2014).

Plants are effective remediators, they have the ability of reaching contaminants through their root systems, accumulate and degrade organic compounds. This explains the TPH (Total petroleum hydrocarbon) and THC (Total hydrocarbon content) accumulation in the test plant observed in this study. This implies that *A. tectorum* has the potential for phytoremediation of petroleum hydrocarbon. This is in line with the review report by Truu *et al*. (2015) that plants remove organic and inorganic contaminants from soil by roots, transport and concentrate them in the harvestable part of the plant (accumulation). The contaminants are either transpired to the atmosphere (phytovolatilization) through the plant leaf stomata or could be metabolized inside the plant; a process referred to as phytodegradation leading to the reduction of contaminant.

Higher accumulation of TPH and THC obtained in treatments T_2 (polluted soil + *A. tectorum* + 500 g cassava peel) and T_3 (polluted soil + *A. tectorum* + 1000 g cassava peel) compared to that obtained in T_1 (polluted soil + *A. tectorum*) infers that application of cassava peel enhanced phytoremediation potential of *Andropogon tectorum.* The cassava peel decomposed forming humus, thus improved soil nutrient status and microbial activity at the rhizophere. The rhizospheric microorganisms increase plant nutrient availability which in turn support plant growth, production of plant growth regulators, decreasing plant stress hormone levels, increasing uptake, accumulation and breakdown of pollutants before they cause harm to the plant (Segura *et al*., 2009; Panz and Miksch, 2012).

CONCLUSION

Enhancing phytoremediation of petroleum hydrocarbon contaminated soil with cassava peel using *Andropogon tectorum* was observed to significantly reduce TPH and THC than the un-amended soil. Application of cassava peel improved soil properties and reduced toxicity of crude oil to the plant and also served as nutrient source for growth of hydrocarbon degrading microorganisms. Thus addition of cassava peel to crude oil polluted soil significantly enhanced the potential of *Andropogon tectorum* in phytoremediation.

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