SOIL PROPERTIES AS INFLUENCED BY INTERACTION OF CRUDE OIL POLLUTION LEVELS WITH PLANT SPECIES IN THE TROPICAL RAIN-FOREST BELT, NIGERIA

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ABSTRACT

A study was conducted at the screen house of the Teaching and Research Farm of Akwa Ibom State University, to evaluate the effects of crude oil pollution levels grown with different native plant species on some physicochemical properties of the soil. A 13 x 4 factorial comprising of twelve varieties of native plant species (Axonopus compressus, Pennisetum purpureum, Eleusine indica, Panicum maximum, Leuceana leucocephala, Gliricidia sepium, Talinum fructicosum, Chromoleana odorota, Cyperus rotundus, Calapogonium mucunoides, Jatropha curcas, Centrosema pubescens) and a control, polluted with four levels (0, 2.5, 5.0 and 7.5 %) of crude oil (w/w) were fitted into Completely Randomized Design with three replications. Significant interactions were observed between crude oil pollution levels and different plant species used on the soil chemical properties while there was no significant effect on the texture of the soil irrespective of the plant species used. Different plant species interact differently in crude oil polluted soils. At 2 and 4 months after crude oil pollution, increase in crude oil pollution level significantly ($P < 0.05$) decreased the values of soil pH, available phosphorus, exchangeable bases and effective cation exchange capacity (ECEC) while organic carbon, total nitrogen and base saturation were significantly ($P < 0.05$) increased relative to the control (unpolluted soil).

Keywords: Crude oil, plant species, pollution, soil properties

1. INTRODUCTION

The progress of civilization since independence has been phenomenal, but rapid industrialization also brought with it the danger of soil pollution. Today, everything around us like the air we breathe and the water we drink even the soil we grow our crops on is severely polluted. Pollution of agricultural soils is one of the most prevalent problems associated with the exploration and processing of petroleum hydrocarbon (Ayotamuno *et al.*, 2006).

Crude oil otherwise known as black gold is a major source of revenue and support for Nigeria economy. Increased in population coupled with the high demand for petroleum products has eventually results in oil spills in the environment. This oil is mainly discharged into the environment through leakages from pipe-line or flow-line, hose failure, sabotage and perhaps during accident (Odu, 2000). In Nigeria especially in the Niger Delta region, it has been estimated that about 0.7-1.7 millions of tons per year of crude oil is spilled into agricultural soils, oceans and rivers.

Crude oil comprises of both hydrocarbon and non- hydrocarbon compounds, including metallic elements such as copper, uranium, nickel, iron, vanadium, lead, cadmium and aluminium (Bremmer *et al*., 1973). These pollutants have been found to affect and alter the chemical and biological properties of soils. Pollution occurs when a change in the environment adversely affects the quality of human life including soil and plants. Some Nigerian researchers like Eneje and Ebomotei (2011) noted that, pollution of soils with crude oil increases soil organic carbon, bulk density and reduces soil water holding capacity, exchangeable cations, soil nitrate and phosphorus while Ijah and Antai (2003) observed a decrease in soil pH of crude oil polluted soil.

The survival of any human being depends on the quality of the soil. Chaney *et al.* (2005) observed that subsistence farmers feeding on rice grown on polluted soils especially hydrocarbon polluted soil are at risk from dietary exposure to cadmium. Soil supports terrestrial life through detoxification of pollutants, biomass production, restoration and resilience of ecosystems and cycling of some nutrients like carbon, boron, phosphorus, sulphur and water (Lal, 2001). Soil quality is depleted as the soil is contaminated through individual or combined processes such as crude petroleum oil pollution. When a soil is polluted, its capacity to produce is reduced.

Contamination of soils with petroleum hydrocarbon and their subsequent degradation has become a major concern because of the critical role of soil resources in promoting sustainable environment and economic development. Both inorganic and organic compounds in soils may not only adversely affect their production potentials but may also compromise the quality of the food chain and the underlying ground water.

The environmental consequences of crude oil pollution on soil properties are enormous. Oil pollution is of a great concern the world over. Even at the micro-level, contamination of the environment by crude oil is a global problem in that it leads to loss of vegetation, food insecurity and biodiversity. Based on the detrimental effects of crude oil pollution on soil and plants and its negative effects on food security as well as the environment, this study evaluates the effects of various levels of crude oil pollution grown with different plant species on soil physicochemical properties of the Niger Delta Region of Nigeria.

2.0 MATERIALS AND METHODS

2.1 Experimental site

The experiment was conducted in the Screen House of the Teaching and Research Farm of the Faculty of Agriculture, Akwa Ibom State University, Obio Akpa Campus in Oruk Anam Local Government Area. Obio Akpa is situated between latitude $4^{o}30^{1}$ and $5^{o}30^{1}$N and longitude 7^{o} 31^{1} and $8^{o}0^{1}$E (SLUK, 1989). The mean annual temperature ranges between 24^{O}C -30^{o}C, while relative humidity ranges between 75 – 79% (SLUK, 1989). Obio Akpa is located in the tropical rainforest belt of Nigeria with a bimodal annual rainfall range of about 2000 to 2500 mm. The rainy season normally starts from March to late October following the dry season from November to late February. The soils of Obio Akpa are mainly acid sands with a pH of 4.9 – 6.1 with high buffering capacity in the order 2.0-10.0 meq/100g soil, low base saturation, high exchangeable aluminium and low nutrient status with severe leaching.

2.2 Experimental materials/sources and preparation

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Top soil (0-30 cm) was taken from the Teaching and Research Farm of the Faculty of Agriculture, Akwa Ibom State University, Obio Akpa Campus using a spade. The soil was thoroughly mixed, air dried and sieved through a 4 mm sieve to remove debris and large stones. Crude oil was obtained from Shell Petroleum Development Company (SPDC) Limited, Port Harcourt, Rivers State, Nigeria while 156 plastic buckets (5 litres capacity) were purchased from the market. The buckets were perforated at the bottom to allow for easy drainage and facilitate aeration. Commonly found native plants around the oil spill regions were selected amongst the grasses, legumes, arable crops and shrubs for the study. Seeds of *Jatropha (Jatropha curcas)* and stems of water leaf (*Talinum fructicosum*) were purchased from the local market, grasses and legumes were transplanted within the experimental area while shrubs were collected from the Department of Forestry, University of Uyo, Akwa Ibom State.

2.3 Treatments, experimental design, application and planting

Twelve varieties of plant species *(Axonopus compressus*, *Pennisetum purpureum*, *Eleusine indica*, *Panicum maximum*, *Leuceana leucocephala*, *Gliricidia sepium*, *Talinum fructicosum*, *Chromoleana odorota*, *Cyperus rotundus*, *Calapogonium mucunoides*, *Jatropha curcas*, *Centrosema pubescens)* and a control (no plant) were grown in soils polluted with four levels of crude oil (0, 2.5, 5.0 and 7.5 % (w/w)). The experiment was laid out as a 13 x 4 factorial fitted into a Completely Randomized Design with three replications.

To each of the perforated plastic bucket was added 5 kg of the 4 mm sieve soils. Crude oil was added to the soil in the pot at various levels of pollution (w/w) of 2.5% (147.5ml), 5% (295ml), 7.5% (442.5ml) and the control at 0%. The crude oil was thoroughly mixed with the soil for even distribution and was watered to field capacity as and when necessary. One week after pollution, *Jatropha* seedlings, *Leuceana leucocephala* and water leaf stems averaging 5cm in height were transplanted from the nursery and one seedling was sown in each pot to a depth of 5 cm. Grasses and legumes were transplanted within the experimental area, while *Gliricidia sepium* was planted by stem cuttings. The pots were uniformly irrigated on the day of sowing and at regular intervals. The duration of the pot experiment was four months.

2.4 Soil sampling and processing

Composite surface soil sample (0-30 cm depth) was randomly collected from the experimental soil before the commencement of the experiment and also at the end of the experiment from each bucket. Soil samples were collected per pot at 2 and 4 months for laboratory analysis. The soil samples were air dried, crushed and sieved through a 2 mm mesh sieved and stored for onward laboratory analysis. The samples for analysis of organic carbon and total nitrogen were further ground and sieved through 0.5 mm mesh.

2.5 Laboratory Studies

The following analyses were carried out on the soil samples using standard procedures as described by Udo *et al*. (2009): Particle size distribution was determined by the Bouyoucous hydrometer method using sodium-hexametaphosphate as a dispersing agent. The soil texture was

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determined from percent sand, silt and clay using the USDA textural triangle. Soil pH was determined using a ratio of 1:2 in soil-water medium and read with a digital pH meter. Organic carbon content was determined by Walkley-Black dichromate oxidation method. Organic matter was obtained by multiplying total carbon by a factor of 1.724. Total nitrogen (N) was determined by the micro-kjedahl method. Available phosphorus (P) was extracted by the Bray 1 extraction method, and the content of P was determined colorimetrically using a Technico AAII auto analyser (Technico, Oakland, Calif). Determination of exchangeable bases was by neutral ammonium acetate extraction and read with an atomic absorption spectrophotometer (AAS). Exchangeable acidity was determined by the 1 N potassium chloride (KCl) extraction method and titrated with 1 M sodium hydroxide (NaOH) using phenolphthalein as an indicator. The effective cation exchange capacity (ECEC) was determined by the summation of total exchangeable bases and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100.

Sample of the crude oil used for the study was also subjected to chemical analysis using standard procedures as described by Udo *et al.* (2009).

3.0 RESULTS AND DISCUSSION

3.1 Properties of the soil and crude oil used for the study

The results of the physico-chemical properties of the soil before crude oil application are shown in Table 1. Particle size distribution was dominated by sand with texture being loamy sand. Soil pH was slightly acidic (6.1), available phosphorous (41.29mg/kg) was high while organic carbon (0.29%) and total nitrogen (0.10%) were low as classified by Chude *et al*. (2012). Exchangeable calcium (6.40 cmol/kg) and magnesium (3.28 cmol/kg) were moderate while exchangeable potassium (0.12 cmo/kg) and sodium (0.06 cmol/kg) were low. Total exchangeable bases and effective cation exchange capacity (ECEC) were moderate while base saturation was higher than the 50% recommended as being the lower limit of base saturation for crop production (Udo *et al*., 2009).

Table 2 shows the chemical properties of the crude oil used for the study. The crude oil has specific gravity of 0.834 g/cm^3, viscosity (CP) 0.28, carbon (85.6%), hydrogen (12.61%), sulphur (1.48%), nitrogen (0.47%), oxygen (0.50%), trace metals (0.13%) and gas-oil ratio of 88.1.

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Table 1: Physicochemical properties of soil before crude oil pollution

Parameters	Values
Sand (%)	88.60
Silt (%)	4.50
Clay (%)	6.90
Textural class	loamy sand
Bulk density (g/cm)	1078
Total porosity (%)	32.5
pH (H_2O)	6.1
Organic carbon (%)	0.29
Total nitrogen (%)	0.10
Available phosphorous (mg/kg)	41.29
Exchangeable bases(cmol/kg)	
Exchangeable Ca	6.40
ExchangeableMg	3.28
ExchangeableNa	0.06
ExchangeableK	0.12
Total exchangeable bases (cmol/kg)	9.86
Exchange acidity (cmol/kg)	2.72
ECEC (cmol/kg) 12.58	
Base saturation (%)	78.3

Table 2: Characteristics of crude oil used for the study

Parameters	Specific values
Specific gravity(g/cm^3)	0.834
Viscosity(CP)	0.28
Carbon (%)	85.5
Hydrogen (%)	12.61
Sulphur (%)	1.48
Nitrogen (%)	0.47
Oxygen (%)	0.50
Trace metals (%)	0.13
Gas oil ratio	88.1

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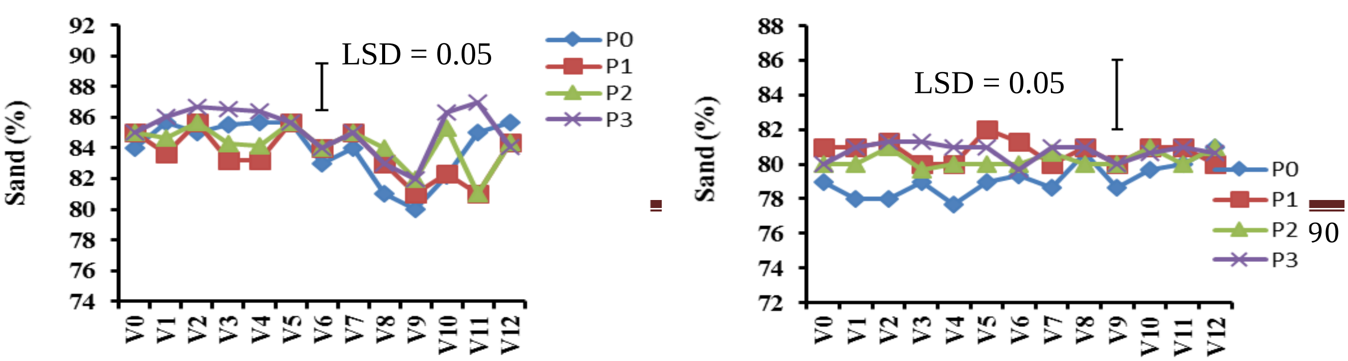
3.2 Interactive effects of crude oil pollution levels and different plant species on some soil physicochemical properties at 2 and 4 months after pollution

The interactive effects of crude oil pollution levels and different plant species on particle size distribution of the soil at 2 and 4 months after pollution (MAP) are shown in Figure 1. The results obtained showed that application of different levels of crude oil to soils planted with different plant species had no significant ($P>0.05$) effect on sand, silt and clay contents of the soil compared with the unpolluted soils (Po). The soil texture was still loamy sand in all the soils irrespective of pollution levels and the plant species used. This confirms the findings by Abosede *et al.* (2013) who reported that pollution of soil with crude oil had no significant effect on textural classes of the soil when compared with the control soils. Similarly, Marinescu *et al.* (2001) also reported no significant effect in crude oil pollution on granulometric fraction of the soil.

At 2 MAP, there were significant reductions in the soil pH (Figure 2) of polluted and planted soils when compared with the absolute control soils that were not planted (Vo) and not polluted (Po). The lowest pH value was obtained in soil polluted with 7.5% (P3) crude oil and planted with *Panicum maximum* (V_4). At 4 MAP, soil pH was significantly increased in all the unpolluted soils (P_0) except in soils planted with *Chromoleana odorata* (V_8), *Cyperus rotundus* (V_9), *Calapogonium mucunoides* (V_{10}) and *Jatropha curcas* (V_{11}). The lowest value of soil pH was obtained in soils polluted with 5.0 (P2) and 7.5% (P3) crude oil without plant (Vo) followed by soils polluted with 2.5 and 5.0% crude oil and planted with *Gliricidia sepium* (V_6). Generally, the results indicated that, polluted soils were more acidic than the control (P_0) and also compared with the value (6.1) obtained before experiment. The relatively lower soil pH obtained in soils polluted with crude oil compared with the control pots may be attributed to the acidic nature of the oil. The result obtained from this study, is in line with the findings of Osuji and Nwoye (2007) who reported that soil pH was reduced due to the presence of hydrocarbon that produce organic acids when acted upon by microorganisms. Ijah and Abioye (2003) also observed decreases in pH value in polluted soils.

The organic carbon content of the soil differed significantly ($P<0.05$) among the different treatments at 2 and 4 MAP (Figure 3) with the polluted soils having higher values and increasing significantly as the level of pollution increases than the unpolluted soils. The increase in organic carbon content observed in this study may be due to the fact that, organic carbon is a major component of crude oil. Similarly, Ogboghodo *et al.* (2004), Ijah *et al.* (2008) and Eneje and Ebomotei (2011) also reported increases in percent organic carbon with crude oil pollution and attributed this to microbial mineralization of crude oil in the soil.



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(a) (b)

(a) Sand at 2 months after pollution (b) Sand at 4 monthsafter pollution

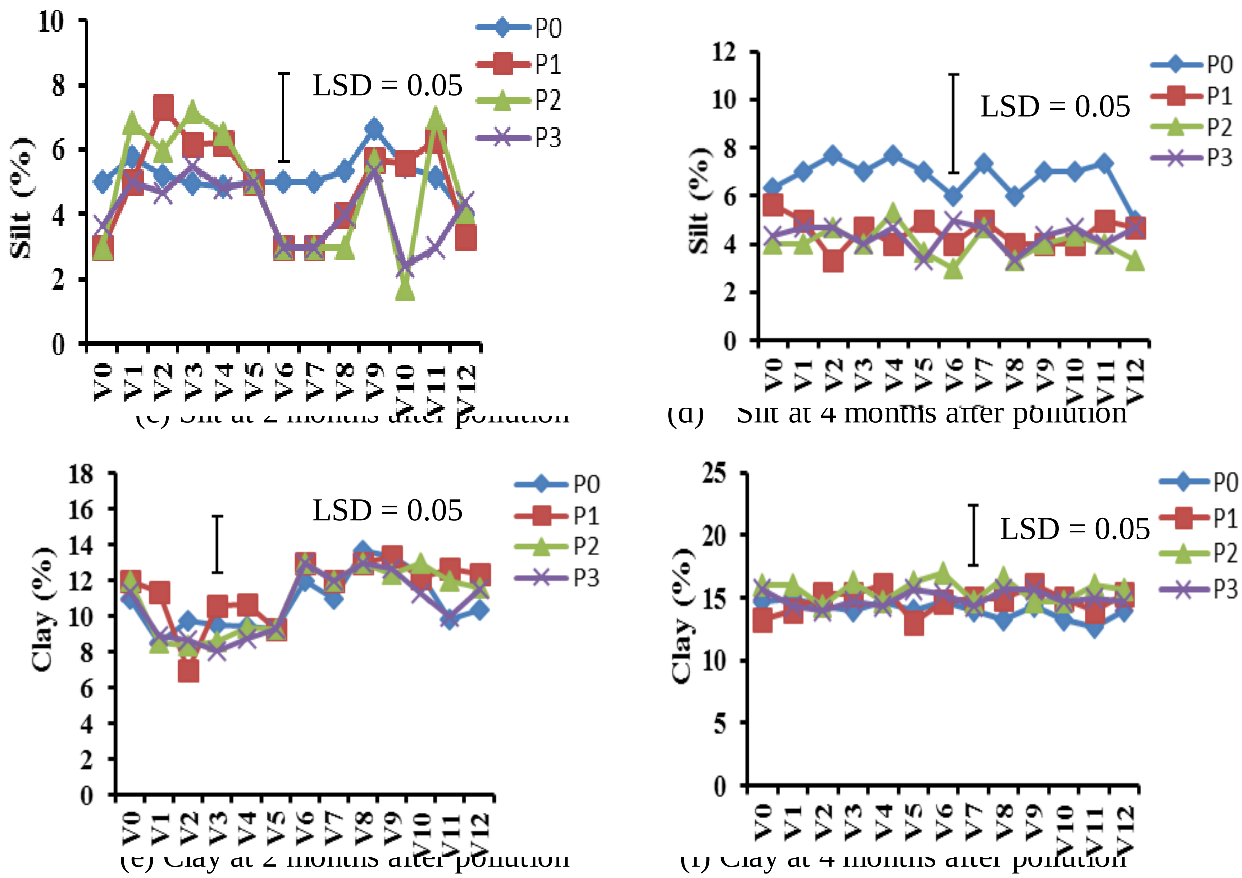
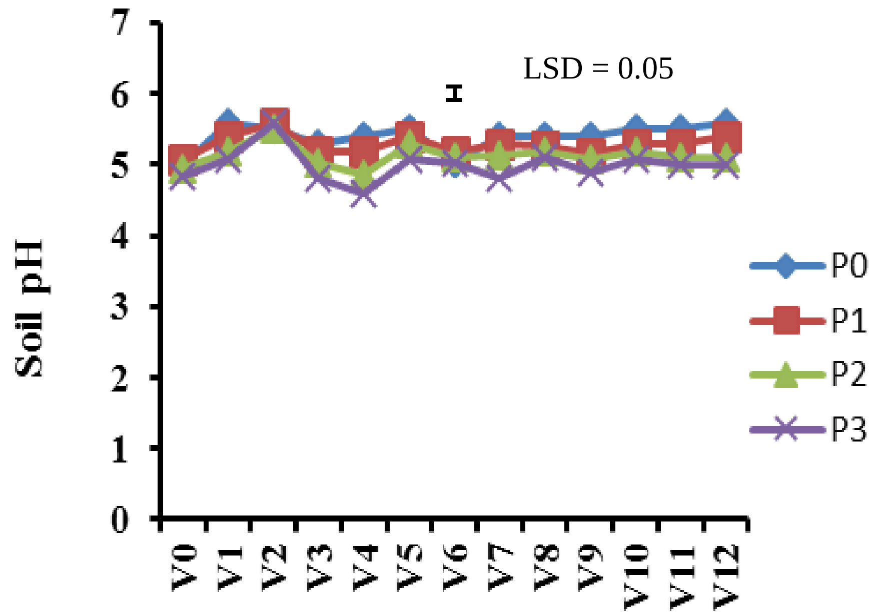
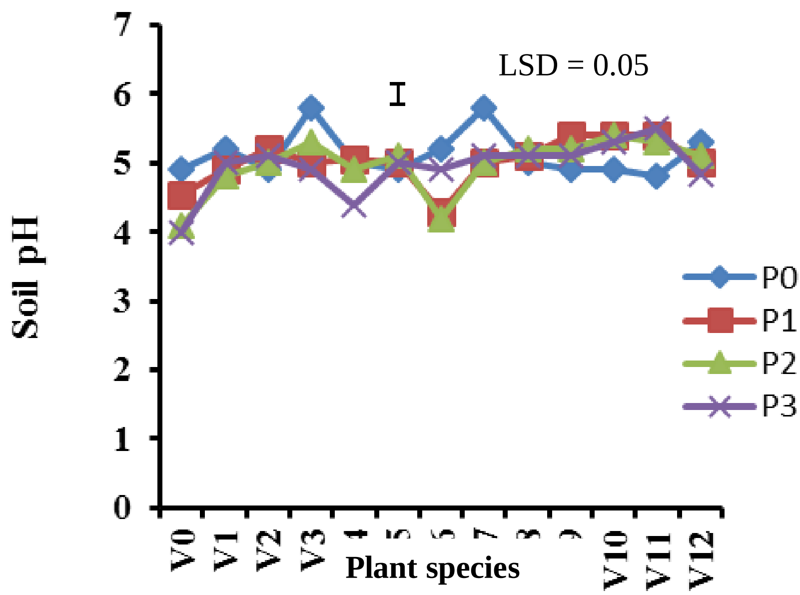


FIG. 1: Interactive effects of crude oil pollution and different plants species on sand (a, b), silt (c, d) and clay (e, f) at 2 and 4 months after pollution

V_o=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=*Goose* weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5= White lead tree (*Leuceana leucocephala*), V_6=Gliricidia (*Gliricidia sepium*), V_7=Waterleaf (*Talinum fructicosum*), V_8=Siam weed (*Chromoleana odorata*), V_9=Nut Sedge weed (*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).





(b)Soil pH at 4 months after pollution

FIG. 2: Interactive effects of crude oil pollution and different plants species on soil pH at(a) 2 and (b)4 months after pollution

V_o=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=*Goose* weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5= White lead tree (*Leuceana leucocephala*), V_6=Gliricidia (*Gliricidia sepium*), V_7=Waterleaf

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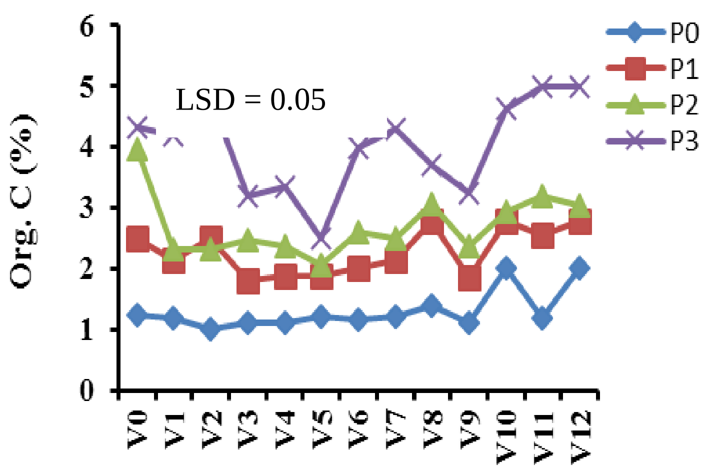
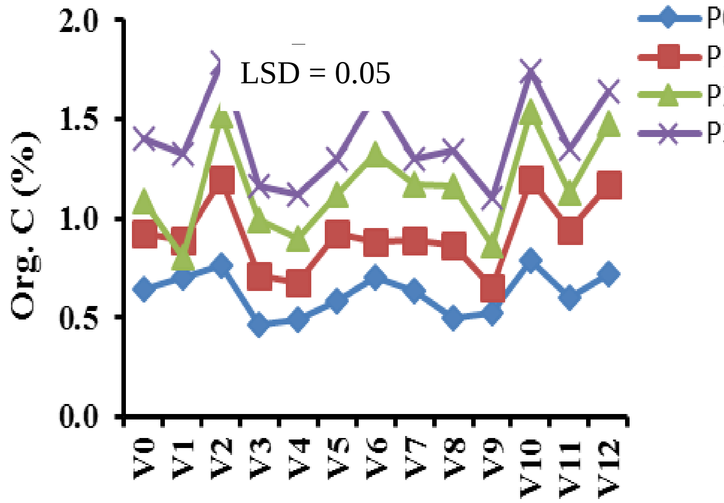
(*Talinum fructicosum*), V_8=Siam weed (*Chromoleana odorata*), V_9=Nut Sedge weed(*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).

The interactive effects of different levels of crude oil polluted soil and plant species on soil nitrogen are shown in Figure 4. At 2 MAP, percent nitrogen was significantly ($P<0.05$) higher in soil polluted with 7.5% crude oil and planted with *Jatropha curcas* (V_{11}), while at 4 MAP the highest value was also obtained in soil polluted with 7.5% crude oil but planted with *Calapogonium mucunoides* (V_{10}).There was a general reduction in the soil total nitrogen level as the growth stage prolonged indicating leaching effect or uptake of this element by the plants. Generally, it was also observed that successive increased in crude oil pollution significantly ($P<0.05$) increased soil nitrogen. The higher content of total nitrogen observed in crude oil polluted soils in this study may be due to the fact that the crude oil contained some nutrient elements such as nitrogen or could also be that crude oil initiates soil reactions that will result in the availability of soil nutrients in the polluted soil. This result is similar to the result obtained by Odu (1972), Udoh (2008) and Eneje and Ebomotei (2011) who reported increases in percent nitrogen in crude oil polluted soils.

Figure 5 shows a significant ($P<0.05$) interactive effects of crude oil pollution levels with plant species on soil available phosphorus (P) content. At 2 MAP, soils treated with 7.5% (P3) crude oil and planted with *Chromoleana odorata* (V_8) significantly decreased the soil available phosphorus content when compared with the control (Po). The soil planted with *Leuceana leucocephala* (V_5) recorded remarkable increases in soil phosphorus content at each of the pollution levels indicating that this plant favours the availability of soil phosphorus. At 4 MAP, the content of soil available phosphorus decreased with increase in pollution level. This agrees with the report of Isirimah *et al.* (1989), Ogboghodo *et al.* (2004) and Eneje and Ebomotei (2011) who observed decreases in available P with increase in pollution. This could be associated with P fixation in the polluted soil.



(a) Organic carbon at 2 months after pollution

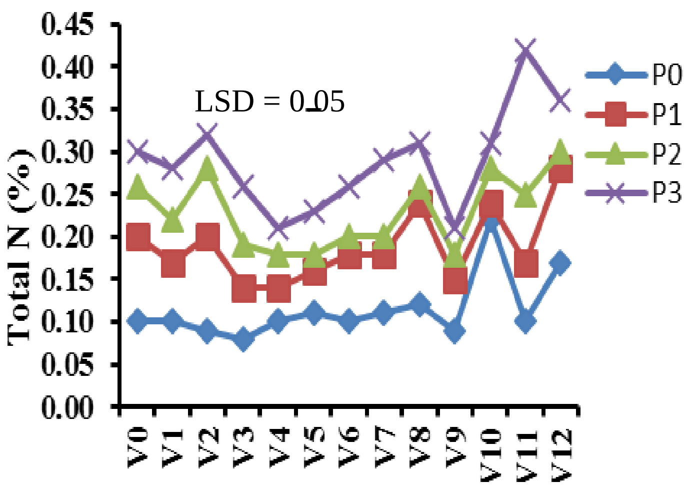


Plant species

(b) Organic carbon at 4 months after pollution

FIG. 3: Interactive effects of crude oil pollution and different plants species on soil organic carbon at (a) 2and (b)4 months after pollution in the screen house

V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White lead tree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf (*Talinum fructicosum*), V_8= Siam weed(*Chromoleana odorata*), V_9= Nut Sedge weed (*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).



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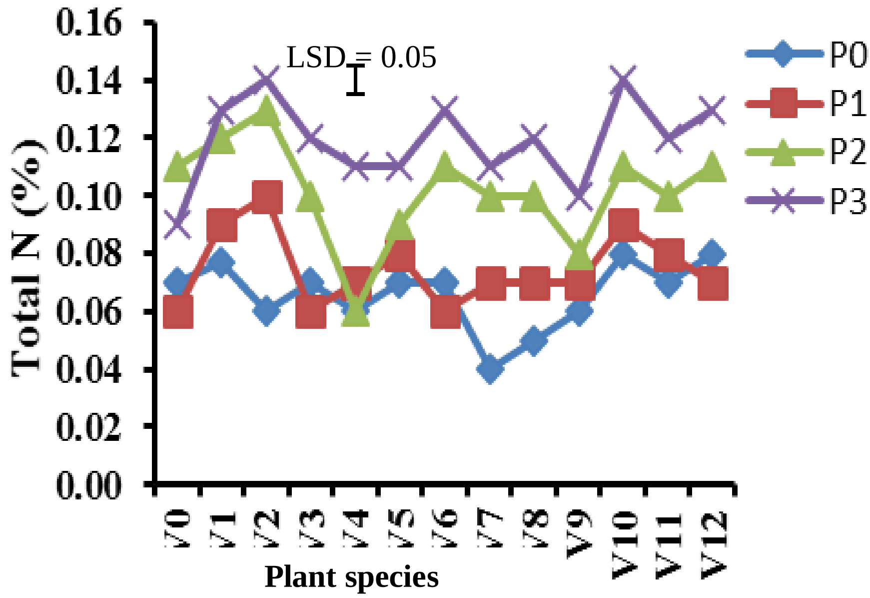
(a) Total Nitrogen at 2 months after pollution



(b) Total Nitrogen at 4 months after pollution

FIG. 4: Interactive effects of crude oil pollution and different plants species on soil total nitrogen at 2 (a) and 4 (b) months after pollution in the screen house.

V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White lead tree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf (*Talinum fructicosum*), V_8= Siam weed (*Chromoleana odorata*), V_9= Nut Sedge weed (*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).

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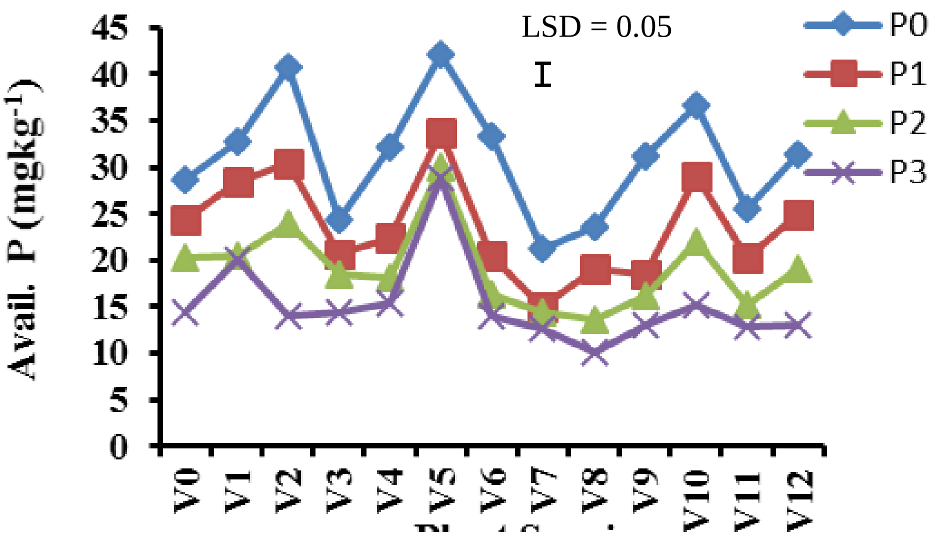

(a) Avail. P at 2 months after pollution

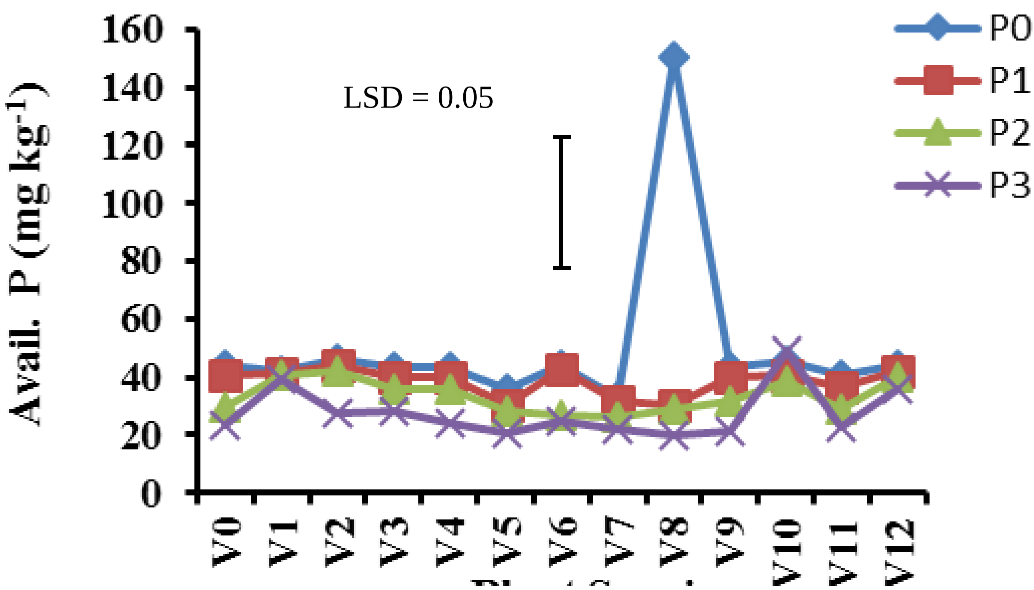

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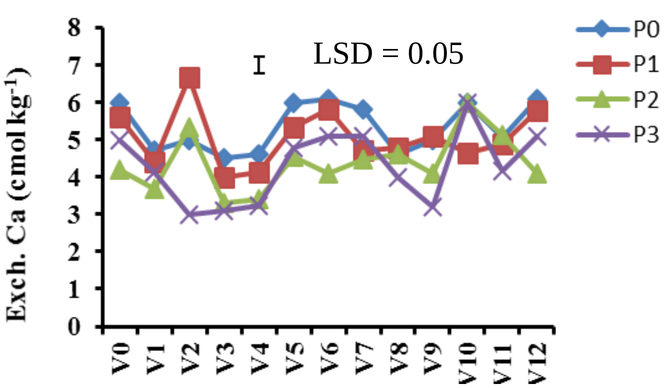
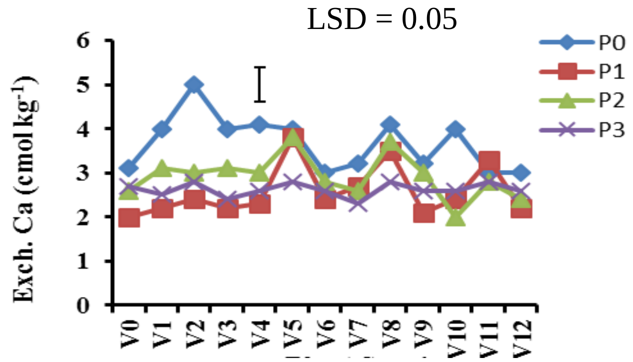
FIG. 5: Interactive effects of crude oil pollution and different plants species on available phosphorus at 2 (a) and 4 (b) months after pollution in the screen house
V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White lead tree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf (*Talinum fructicosum*), V_8= Siam weed (*Chromoleana odorata*), V_9= Nut Sedge weed (*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).

Generally, there were significant reductions in exchangeable calcium (Ca) in the oil impacted soils (Figure 6). The plausible reasons for these decreasing trends may be due to the uptake by plants and temporal immobilization of this nutrient by soil microbes. This result is in consonance with the findings of Obasi *et al.* (2013) and shukry *et al.* (2013) who reported decrease in exchangeable calcium in crude oil polluted soils but contradicts the findings by Eneje and Ebomotei (2011) who observed increase in exchangeable Ca in polluted soils. The observed decrease in exchangeable magnesium (Mg) in some of the treated soils at 4 MAP may be attributed to uptake by the plants as well as leaching losses (Figure 6). At 2 MAP, there were no marked reductions in the exchangeable potassium (K) content of polluted soils when compared with the control, but at 4 MAP, soil polluted with 2.5 and 5.0% and planted with *Axonopus compressus* (V_1) and *Eleusine indica* (V_3) respectively, recorded significant increases compared with other treated soils and the control (Figure 7).This agrees with the observation of Eneje and Ebomotei (2011) who reported increase in K content of polluted soils. There were no significant differences in exchangeable Na concentration in all the treated soils including the control (Figure 7).Generally, the exchangeable bases were low in all the polluted soils when compared with the unpolluted (Po) soils. The decrease in exchangeable bases may be due to nutrient immobilization as a result of the formation of complexes in the soil after uptake by plants. The result obtained in this study is in line with the findings of Eneje and Abomotei (2011) who reported a reduction in exchangeable bases as a result of crude oil pollution.





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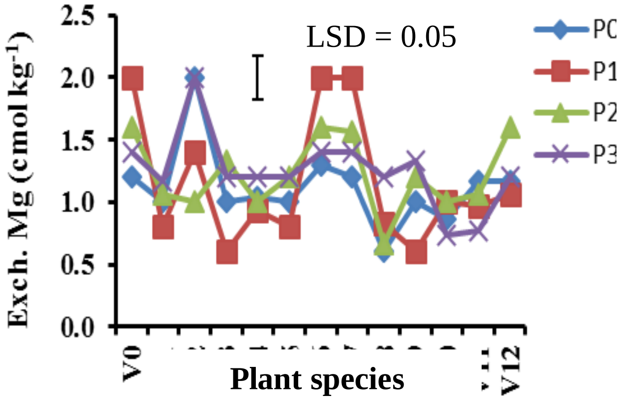
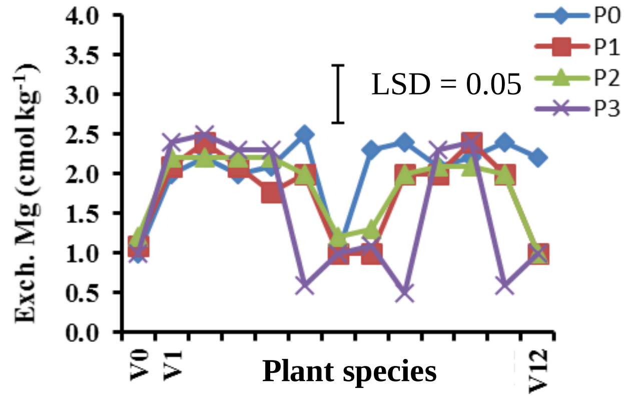
(a)Exch. Ca at 2 months after pollution (b) Exch. Ca at 4 months after pollution

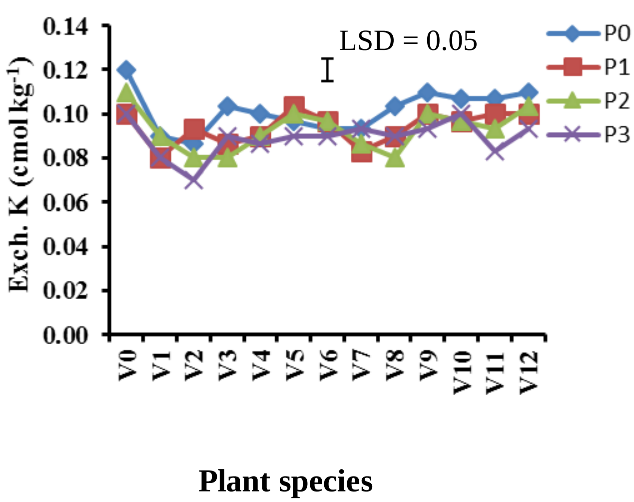


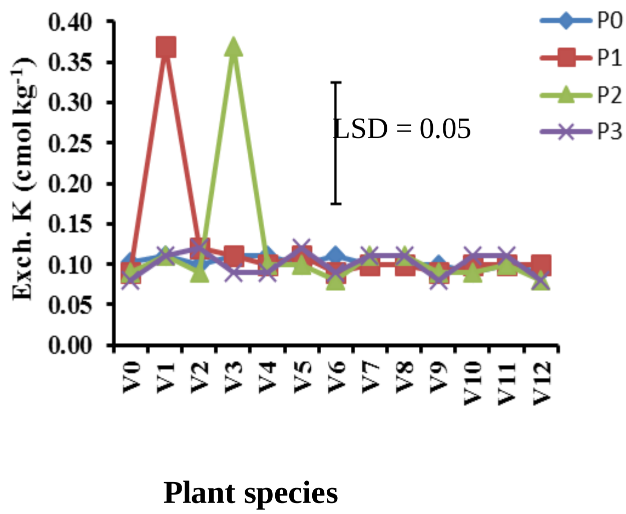


(a) Exch. Mg at 2 months after pollution (b) Exch. Mg at 4 months after pollution

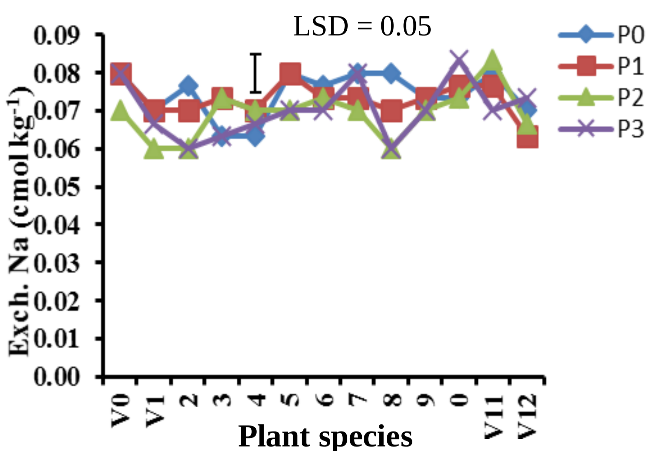
FIG. 6: Interactive effects of crude oil pollution and different plants species on soil exchangeable calcium and magnesium at 2 (a) and 4 (b) months after pollution in the screen house.

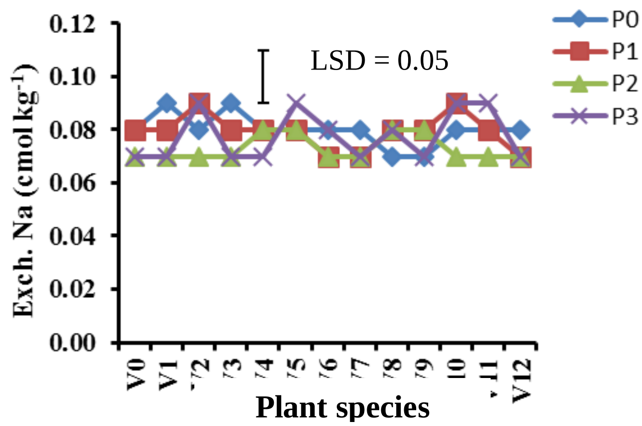
V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White lead tree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf (*Talinum fructicosum*), V_8= Siam weed (*Chromoleana odorata*), V_9= Nut Sedge weed (*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).





(a) Exch. K at 2 months after pollution (b) Exch. K at 4 months after pollution





(a) Exch. Na at 2 months after pollution (b) Exch. Na at 4 months after pollution

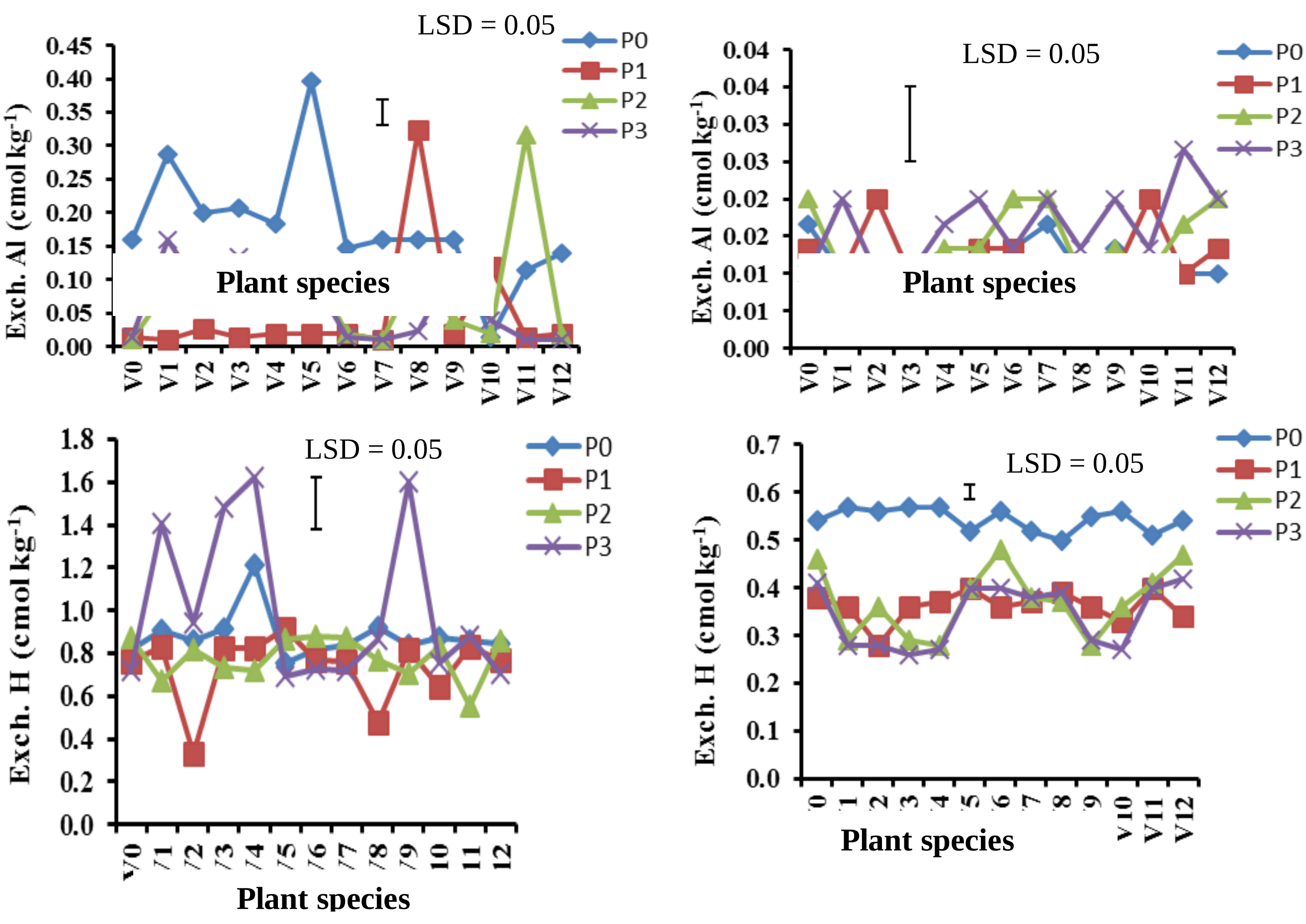
FIG. 7: Interactive effects of crude oil pollution and different plants species on soil exchangeable potassium and sodium at (a)2 and(b)4 months after pollution

V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass(*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass(*Panicum maximum*), V_5=White lead tree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf (*Talinum fructicosum*), V_8= Siam weed (*Chromoleana odorata*), V_9= Nut Sedge weed (*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).

There was significant ($P<0.05$) difference in soil exchangeable A1 concentration at 2 and 4 MAP (Figure 8). Exchangeable Al in the polluted soils were significantly reduced when compared with the unpolluted soils except in soils polluted with 2.5 and 5.0% crude oil and planted with *Chromoleana odorata* (V_8) and *Jatropha curcas* (V_{11}), respectively which had higher concentrations than the control. However, polluted soils especially at higher pollution level recorded higher values of exchangeable Al than the control .For exchangeable H (Figure 8) at 2 MAP, highest concentrations were obtained in soils polluted with 7.5% crude oil and planted with *Axonopus compressus* (V1), *Eleusine indica* (V3), *Panicum maximum* (V4) and *Cyperus rotundus* (V9) and the least was observed in soils polluted with 2.5% crude oil and planted with *Pennisetum purpureum*(V_2) and *Chromoleana odorata* (V_8) while at 4 MAP the unpolluted soils irrespective of the plant species used were significantly higher in exchangeable H concentration than the polluted soils. Significant differences ($P<0.05$) were observed between unpolluted and polluted soils for ECEC at 2 and 4 MAP (Figure 9). The ECEC at 4 MAP was higher in the unpolluted soils than the polluted soils except in soil planted with *Gliricidia sepium* (V_6). Base saturation values were higher in the polluted soils than the unpolluted soils (Figure 10). The highest at 4 MAP was in the 7.5% polluted soil planted with *Calapogonium mucunoides* (V_{10}). This agrees with the report of Eneje and Abomotei (2011) who observed higher base saturation values in polluted soils.

4.0 CONCLUSION

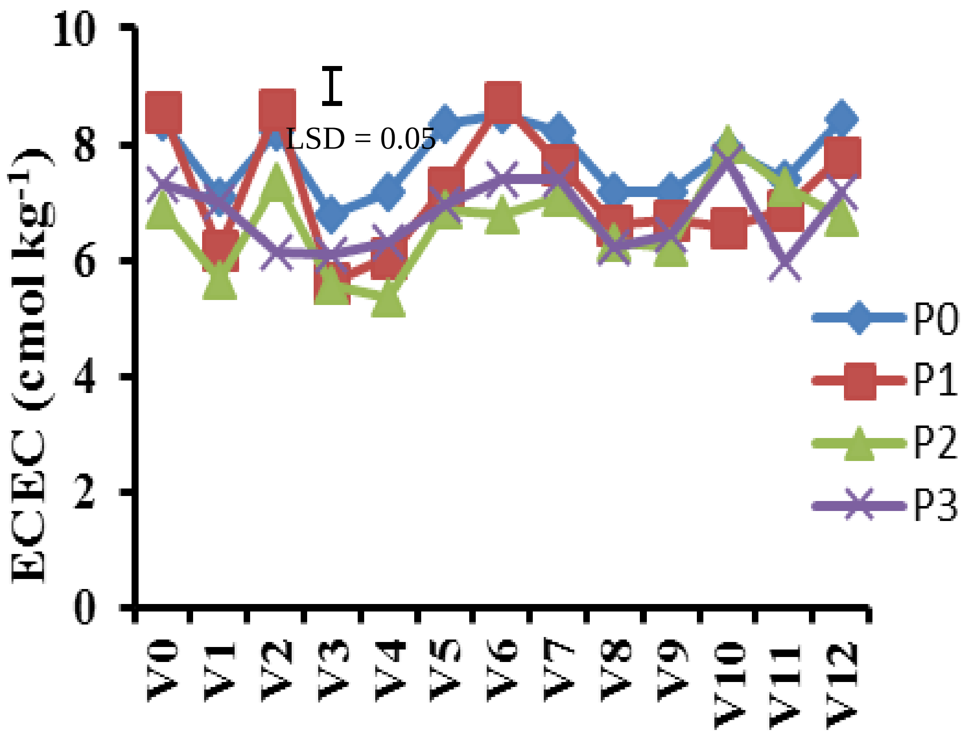
The result obtained from this study revealed that crude oil pollution had no significant effect on the texture of the soil irrespective of the plant species used. Significant interactions were observed between crude oil pollution levels and different plant species used. Different plant species interact differently in crude oil polluted soils. Successive increase in crude oil pollution significantly ($P < 0.05$) decreased the soil pH, available phosphorus, exchangeable bases, exchangeable Al and H, and effective cation exchange capacity while organic carbon, total nitrogen and percent base saturation were significantly ($P < 0.05$) increased.



(a) Exch. H at 2 months after pollution (b) Exch. H at 4 months after pollution

FIG. 8: Interactive effects of crude oil pollution and different plants species on soil exchangeable Al and H at(a)2 and (b) 4 months after pollution

V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass(*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White leadtree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf(*Talinum fructicosum*), V_8= Siam weed(*Chromoleana odorata*), V_9= Nut Sedge weed(*Cyperus rotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).



(a) ECEC at 2 months after pollution

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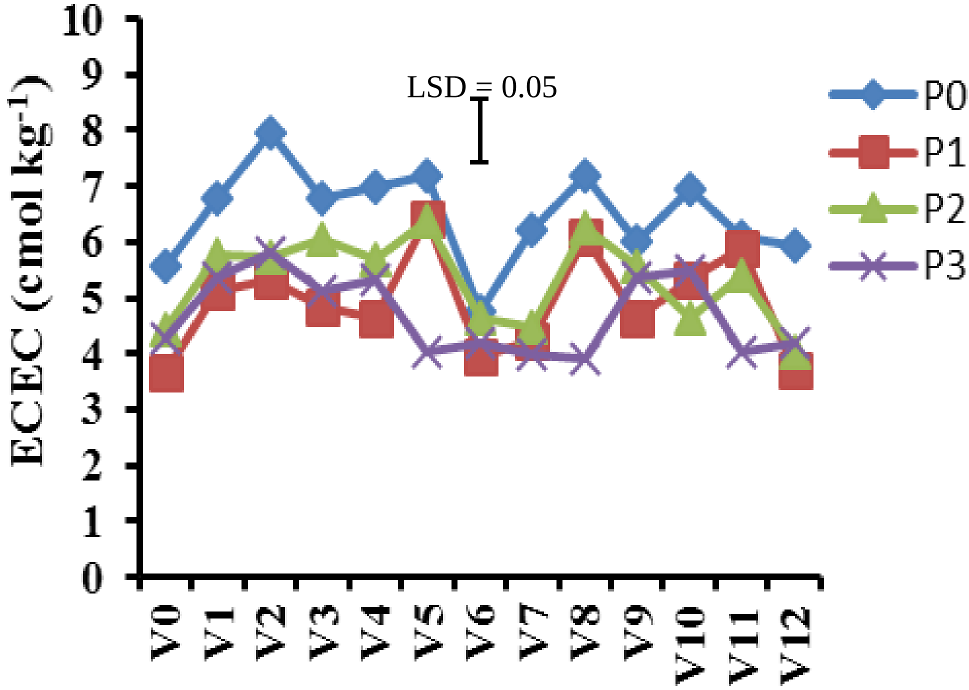

Plant species

(b) ECEC at 4 months after pollution

FIG. 9: Interactive effects of crude oil pollution and different plants species on effective cation exchange capacity (ECEC) at 2 (a) and 4 (b) months after pollution

V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White leadtree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidia sepium*), V_7= Waterleaf (*Talinum fructicosum*), V_8= Siam weed (*Chromoleana odorata*), V_9= Nut Sedge weed(*Cyperusrotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).

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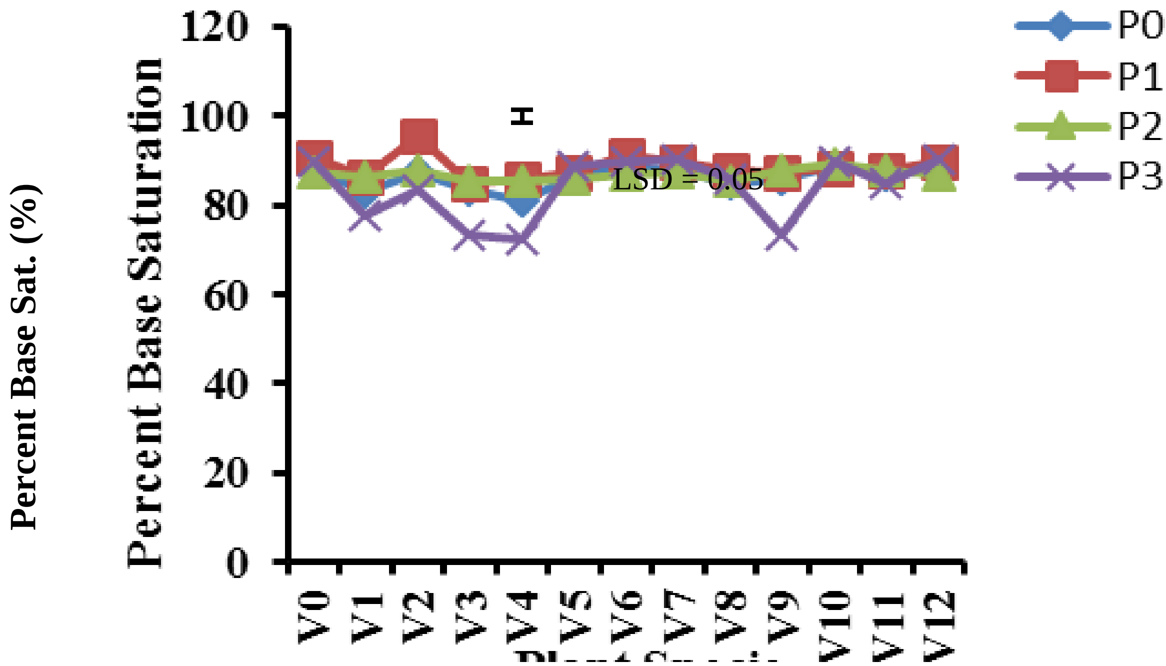

(a) Percent Base Sat. at 2 months after pollution

Plant species

(b) Percent Base Sat. at 4 months after pollution

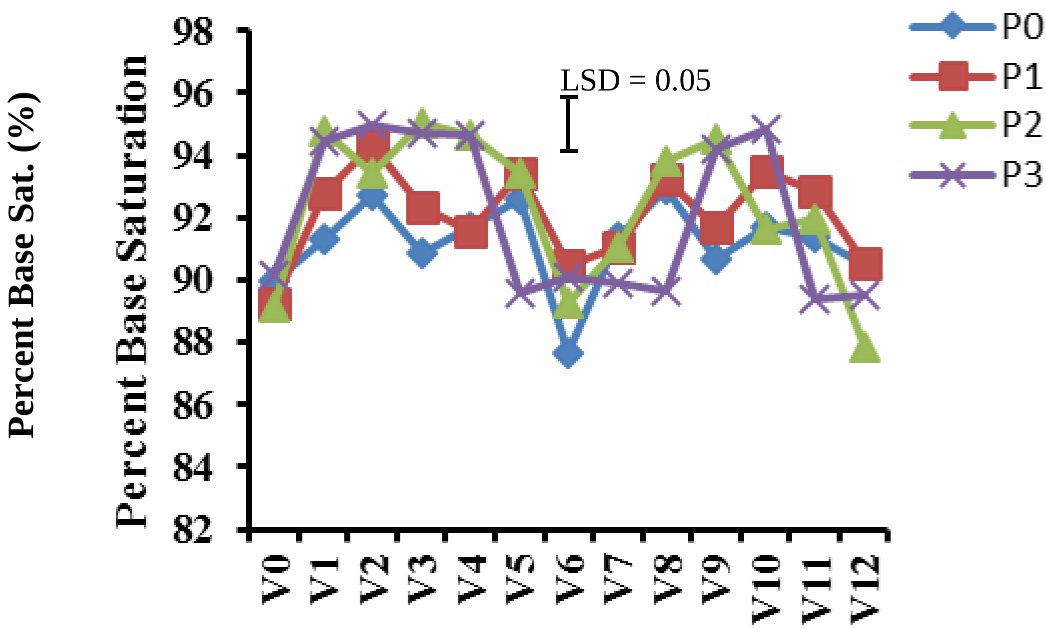

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FIG.10: Interactive effects of crude oil pollution on percent base saturation at 2 (a) and 4 (b) months after pollution in the screen house.

V_0=No plant species, V_1= Carpet grass (*Axonopus compressus*), V_2= Elephant grass (*Pennisetum purpureum*), V_3=Goose weed (*Eleusine indica*), V_4= Guinea grass (*Panicum maximum*), V_5=White lead tree (*Leuceana leucocephala*), V_6= Gliricidia (*Gliricidiasepium*), V_7= Waterleaf(*Talinumfructicosum*), V_8= Siam weed (*Chromoleana odorata*), V_9= Nut Sedge weed (*Cyperusrotundus*), V_{10}=Calapo (*Calapogonium mucunoides*), V_{11}=Jatropha (*Jatropha curcas*), V_{12}=Centro (*Centrosema pubescens*).

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