International Journal of Recycling of Organic Waste in Agriculture (2021)10: 415-426
Doi: 10.30486/IJROWA.2021.1899855.1073

ORIGINAL RESEARCH

Effects of organic manures bioremediation on growth performance of Maize (*Zea mays* L.) in crude oil polluted soil

Stella Eberechukwu Obasi[1*], Nwogo Ajuka Obasi[2], Ephraim O Nwankwo[3], Benneth Nnanyelugo Enemchukwu[1], Robert Ikechukwu Igbolekwu[1], Jeff Onochie Nkama[1]

Received: 13 May 2020 / Accepted: 06 July 2021 / Published online: 06 November 2021

Abstract

Purpose Crude oil pollution adversely affects the environment and its remediation presents significant challenge due to its complex nature. Bioremediation approaches have proved effective and the use of organic wastes makes the process eco-friendly. Therefore, this study investigated the effects of organic manures amendments of crude oil polluted soil on the growth and performance of maize (*Zea mays* L.) under potted environment at the botanic garden of University of Port-Harcourt, Nigeria.

Method The loamy soils in different pots (5.0 kg each) were polluted with crude oil in six factorial treatments set (0.0%, 2.0%, 4.0%, 6.0%, 8.0% and 10.0%) and allowed for two weeks. Thereafter, the polluted soils were subjected to different organic manure amendment: poultry-manure, cow-dung, saw-dust, combined poultry-manure + cow-dung, combined poultry-manure + saw-dust and combined cow-dung + saw-dust manures with two sets of control: polluted soil + no organic manure and non-polluted soil + no organic manure. The amended soils were allowed for two weeks before sowing viable maize seeds and the seedling monitored every two weeks after germination for a period of eight weeks.

Results Crude oil pollution impaired the maize seed germination, growth and development. Organic manures amendments of polluted-soil significantly improved ($P \leq 0.05$) maize plant agronomic characteristics with combined manures especially poultry-manure + cow-dung showing highest improvement than other combined or single manure treatment.

Conclusion Combined organic manures amendments of crude oil polluted soil especially cow-dung + saw-dust were found to be environmentally friendly and beneficial for maize crop production.

Keywords Crude oil pollution, Waste management, *Zea mays* L., Bioremediation, Crop production, Agronomic characteristics

Introduction

Crude oil spillage occurs regularly in the Niger Delta region of Nigeria where over 80% of the crude oil is produced. In Nigeria, numerous oil fields, tank farms, flow stations, pipelines, tankers and loading jetties constantly cause crude oil pollution especially in Niger Delta areas (Chikere and Chijioke-Osuji 2006; Bebeteidoh et al. 2020). These oil spillages introduce various organic and inorganic chemicals, some of which are non-carcinogenic (growth-inhibiting) and others carcinogenic chemicals, to the environment with direct impact on microorganisms, plants and humans (Okpokwasili and Odokuma 1990; Njoku et al. 2009; Aboh and Isitekhale 2013). Crude oil pollution adversely and drastically affects soil physicochemical properties and many studies (Baker and Herson 1994; Okolo et al. 2005; Liang et al. 2012) have reported its adverse effects on soil ecosystem to include but not limited to absorption to soil particles, provision of an excess carbon that might be unavailable for microbial

✉ Stella Eberechukwu Obasi
stellaeobasi@gmail.com

[1] Plant Ecology Research Unit, Department of Science Laboratory Technology, School of Science, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria
[2] Environmental Biochemistry, Health and Toxicology Research Unit, Department of Medical Biochemistry, Alex Ekwueme Federal University Ndufu-Alike, Ebonyi State, Nigeria
[3] Department of Applied Biology, Faculty of Biological Science Ebonyi State University, Abakaliki, Ebonyi State, Nigeria

use and induction of a limitation in soil nitrogen and phosphorus. The damaging effects of crude oil pollution on soil microorganisms, plant growth and development have been reported (Amakiri and Onofegbara 1983; Njoku et al. 2008; Adedokun and Ataga 2007; Aboh and Isietekhale 2013). Onuha et al. (2008) reported that crude oil pollution prevents oxygen exchange in soil (reduce soil aeration) due to the hydrophobic properties of crude oil and as such affects soil life.

Also, crude oil pollution causes increase in soil acidity which in turn sets an imbalance in soil ecosystem (Asuquo et al. 2010). Other adverse effects of crude oil pollution on plant growth and development include wilting, chlorosis, tissue and cell maceration, blotching to collapse of marginal necrotic spots and eventually, death of the plants (Chorom et al. 2010; Ofoegbu et al. 2015)

Maize (*Zea mays* L.) is recognized as a leading commercial crop of great agro-economic value owing to its expanded use in the agro-industries (Rasheed and Mahmood 2004). It is a major popular staple food consumed in large quantities by the teaming population of Nigeria and ranking third in the world production of cereal after wheat and rice (FAO 2002). Other main uses of maize include livestock feed and as raw materials for numerous industrial products (Gbogidi et al. 2007). Maize is the main stay of many countries forming the highest source of energy in the national diet of many countries of which sixteen are in Africa including Nigeria (Dowswell et al. 1996). The agronomical requirement of maize includes warm sunny weather, nutrient rich and moist well drained soil, high levels of nitrogen for proper growth and development. Thus, addition of organic manures will greatly enhance its productive performance (FAO 2002; Gbogidi et al. 2007).

Adverse effects of crude oil pollution on arable agricultural lands make them unproductive. Therefore, a number of remediation strategies such as the use of surfactants, alternate carbon substrates, organic and inorganic manures have evolved to reclaim the land and make them productive (Raskin et al. 1997; Burd et al. 2000; Okolo et al. 2005; Ijah et al. 2008; Onuh et al. 2008a, b; Chorom et al. 2010; Hamoudi-Belarbi et al. 2018). Remediation strategies which could be by physical, chemical or biological (bioremediation) techniques are those treatments or techniques used to restore a polluted or contaminated environment (soil, water and air) (Odu 2006; Chorom et al. 2010; Hamoudi-Belarbi et al. 2018). Bioremediation techniques or processes are the use of microorganisms or products of biological origin to remove environmental (soils/sediments, water and air) pollutants via microbial degradation of organic and inorganic contaminants (Chorom et al. 2010; Hamoudi-Belarbi et al. 2018). Bioremediation potentials of crude oil pollution which involves hydrocarbon biodegradation and removal can be limited by many factors such as: microorganism type, nutrients, pH, temperature, moisture, oxygen, soil properties, and contaminant concentration (Demnerova et al. 2005). Despite the limitations, bioremediation of crude oil polluted soils is the cheapest and environmentally friendly approach for reclamation of affected agricultural lands. The increase in the search for cheap protein sources have led to increase in the poultry farms and cattle ranches. These activities have tremendously increased the quantity of poultry and cow dung wastes which creates nuisance to the environment (Ijah et al. 2008; Madukwe et al. 2008). These organic wastes could easily be transformed into nutrient rich manure for eco-friendly bioremediation purposes. Also, increase in technological advancement and the use of timber for a variety of construction and building purposes have increased the rate of generation of saw dust which if not converted to useful manure will constitute environmental pollution (Odu 2006). To reclaim crude oil polluted agricultural soils and still maintain a sustainable ecosystem, application of organic manures is highly recommended due to its eco-friendly nature (Amakiri and Onofegbara 1983; Aboh and Isietekhale 2013). The conversion and application of poultry manure, cow dung and saw dust wastes among others as organic manures for bioremediation purposes will not only reduce environmental pollution caused by the enormous quantities of these wastes generated but will also be useful in tackling the menace of crude oil pollution which always present the environment with recalcitrant pollutants (Cuningham and Philip 2000; Demnerova et al. 2005; Chorom et al. 2010). Organic manures have been used singly or in combination to improve soil fertility over the years (Amadi et al. 1996; Okolo et al. 2005; Ijah et al. 2008; Onuh et al. 2008a, b; Agarry et al. 2010). The efficacy of organic bioremediation in promoting plant growth in crude oil polluted Nigerian soil has also been well documented (Amadi and Uebari 1992; Ogboghodo et al. 2005).The effectiveness of these organic manure bioremediation strategies has however been conflicting (Cunningham and Philip 2000; Lee et al. 2002; Lindstrom and Braddock 2002). This has been attributed to the heterogeneity of soils and crude oil samples as well as possible interactions between the soil amendments materials and the natural soil constituents (Knabel et al. 1994). The effectiveness of each treatment in any soil therefore needs to be evaluated on a case specific basis. Therefore, this study is aimed at investigating the potentials of using different organic manures singly and in combination for treatment of crude oil polluted soils and their effects on the growth and development of maize (*Zea mays* L.) plant.

Materials and methods

Study area description

This study was carried out at the University of Port Harcourt Botanic Garden, Port Harcourt, Rivers State of Nigeria located between latitude 4° 00 and 5° 00N, and longitude 6° 30 and 7° E of 26 km, North-West of Port Harcourt, Nigeria.

Sample collection

The experiment was conducted using loamy soils collected from an uncultivated agricultural land in the botanic garden of the University of Port Harcourt, Rivers State. The soil samples were collected randomly using a metal soil auger and a trowel from top surface soil at a depth of 0-15 cm. The soil samples were bulked together using coning and quartering method, homogenized and 5.0 kg weighed into perforated labeled bags and a total of 168 bags were made ready for the experiment. Poultry waste was obtained from poultry farm, cow dung waste was sourced from cow slaughter house and sawdust waste was obtained from a timber milling factory, all located at Aluu area of Chioba in Obio-Akpo LGA, River State, Nigeria. The different organic wastes were separately composted, crushed and packaged as organic manure before use. The crude oil used for the experiment was sourced from Nigeria National Petroleum Corporation (NNPC), Eleme, Port-Harcourt, Rivers State Nigeria. The *Zea mays* L. seeds (Oba super 1 variety) used for the study were obtained from Agricultural Development Programme (ADP) office located at Ruma-Okoro, Port Harcourt, Rivers State.

Pollution treatment and organic manure amendments

Crude oil pollution was applied in different proportions at 0.0, 2.0, 4.0, 6.0, 8.0 and 10.0% in 5.0 kg soil at random blocks comprising I, II, III, IV, V and VI, respectively. The polluted and unpolluted soils were allowed to stand under natural environment for fourteen days before application of processed organic manure amendments. During this period, the soil samples were watered at intervals of two days and mixed to ensure aeration. Thereafter, the soils with different levels of pollution were amended by addition of different organic manures at a ratio of 3:1 soil to organic manure as in the design shown in Table 1. Poultry manure (PM), cow dung manure (CM), sawdust manure (SM) and a combination of equal amount of the manures at predetermined ratio; poultry manure + cow dung manure (PM + CM), poultry manure + sawdust manure (PM + SM) and cow dung manure + sawdust manure (CM + SM). The organic manure treated soils were watered every two days and mixed to ensure adequate aeration and allowed to stand for fourteen days before planting. This study design included double control with four replicates given a total of 168 treatment stands. Progress of the plants performance and development were monitored and weeds from buried seeds were uprooted and removed by hand as they appeared. Plant growth characteristics data were collected on the following: germination percentage (%), plant height (cm), plant leaf number and leaf area (cm^2).

Determination of *Zea mays* L. growth parameters

Plant viability was determined by the flotation method according to the procedures outlined by Agbogidi and Nweke (2005). A bucket was washed with detergent and rinsed with distilled water, inverted and allowed to dry. The dried grease free bucket was then filled with water and *Zea mays* L. seeds were poured into the water. Thereafter, the seeds that settled down at the bottom of the bucket were obtained as viable seeds and five seeds per pot at the depth of 4 cm were used for sowing in the pot experiment.

Germination percentage (%) was determined by counting the number of seedlings that germinated at seven days of sowing and calculated as shown in equation (1).

$$\% \text{ Germination} = \frac{NSGP}{NSPP} \times \frac{100}{1} \quad (1)$$

Table 1 Experimental treatment design and protocol

Crude oil pollution level (%)	Amendment options with different organic manures						
	A (Soil + crude oil)	B (soil + crude oil + PM)	C (soil + crude oil + CM)	D (soil + crude oil + SM)	E (soil + crude oil + PM + CM)	F (soil + crude oil + PM + SM)	G (soil + crude oil + CM + SM)
I (0.0)	5 kg +0.0	kg + 0.0 5 kg 1.67 +	5 kg + 0.0 + 1.67 kg	5 kg + 0.0 + 1.67 kg	5 kg + 0.0 + 0.83 kg + 0.83 kg	5 kg + 0.0 + 0.83 kg + 0.83 kg	5 kg + 0.0 + 0.83 kg + 0.83 kg
II (2.0)	5 kg +2.0	kg + 2.0 5 kg 1.67 +	5 kg + 2.0 + 1.67 kg	5 kg + 2.0 + 1.67 kg	5 kg + 2.0 + 0.83 kg + 0.83 kg	5 kg + 2.0 + 0.83 kg + 0.83 kg	5 kg + 2.0 + 0.83 kg + 0.83 kg
III (4.0)	5 kg +4.0	kg + 4.0 5 kg 1.67 +	5 kg + 4.0 + 1.67 kg	5 kg + 4.0 + 1.67 kg	5 kg + 4.0 + 0.83 kg + 0.83 kg	5 kg + 4.0 + 0.83 kg + 0.83 kg	5 kg + 4.0 + 0.83 kg + 0.83 kg
IV (6.0)	5 kg +6.0	kg + 6.0 5 kg 1.67 +	5 kg + 6.0 + 1.67 kg	5 kg + 6.0 + 1.67 kg	5 kg + 6.0 + 0.83 kg + 0.83 kg	5 kg + 6.0 + 0.83 kg + 0.83 kg	5 kg + 6.0 + 0.83 kg + 0.83 kg
V (8.0)	5 kg +8.0	kg + 8.0 5 kg 1.67 +	5 kg + 8.0 + 1.67 kg	5 kg + 8.0 + 1.67 kg	5 kg + 8.0 + 0.83 kg + 0.83 kg	5 kg + 8.0 + 0.83 kg + 0.83 kg	5 kg + 8.0 + 0.83 kg + 0.83 kg
VI (10.0)	5 kg +10.0	kg + 10.0 5 kg 1.67 +	5 kg + 10.0 + 1.67 kg	5 kg + 10.0 + 1.67 kg	5 kg + 10.0 + 0.83 kg + 0.83 kg	5 kg + 10.0 + 0.83 kg + 0.83 kg	5 kg + 10.0 + 0.83 kg + 0.83 kg

A (I-VI) = Pollution with no remediation treatment, B(I-VI) = Different pollution levels treated with 1.67 kg poultry manure (PM), C(I-VI) = Different pollution levels treated with 1.67 kg cow dung manure (CM), D(I-VI) = Different pollution levels treated with 1.67 kg saw dust manure (SM), E(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg cow dung manure (CM), F(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg saw dust manure (SM), G(I-VI) = Different pollution levels treated with 0.83kg cow dung manure (CM) and 0.83kg saw dust manure (SM)

In equation 1, NSGP is the number of seedling germinated per pot and NSPP is the number of seeds planted per same pot

The plant height (PH) was determined by recording the heights of each seedling from the ground level to the tip of the plant with a thread which is then measured using meter rule. Plant height was determined and recorded at two weeks' intervals up to eight weeks after planting (WAP) (Agbogidi and Nweke 2005).

The number of plant's leaves in the germinated seedlings was counted and the average per plant in the replicated pots recorded. Similarly, the plant's leaf area (PLA) was determined for each leaf by placing a transparent graph sheet on each leaf and the number of squares covered by each was recorded as outlined by Agbogidi and Nweke (2005). The average plant leaf area (PLA) for all the leaves in plants in the replicated pots was determined and recorded at two weeks' intervals up to eight weeks after planting (WAP).

Statistical analysis

The results were expressed as mean + standard deviation (SD) of four replicates. One way analyses of variance (ANOVA) was used to analyze the data while mean values was separated by the Duncan Multiple Range Test (DMRT) using Fishers Least Significance Difference (LSD) (Kerr et al. 2002). Significant differences were established at $P < 0.05$.

Results and discussion

The results of the effects of different organic manure amendments on the percent germination of *Zea mays* L. in the varying degree of crude oil polluted soils are shown in Fig. 1. The results showed 100% germination in crude oil unpolluted soil amended with poultry manure (PM), cow dung manure (CM), combination of poultry manure and cow dung manure (PM + CM) and combination of poultry manure and sawdust manure (PM +SM).The results also showed that the application of sawdust manure to crude oil unpolluted soil gave the least percentage germination rate (80%). Percentage of germination of *Zea mays* L. generally and significantly ($P < 0.05$) decreased with increase in percentage crude oil pollution and at 8.0 and 10.0 % crude oil pollution with no organic manure amendment, all the sown viable seeds did not germinate (Fig. 1). However, amendments with organic manure increased the percentage germination with poultry manure giving the highest. In all instances, however, saw dust manure gave the least percentage of germination. The order of increase in the percentage germination by the different amendments options was: poultry manure (PM) > cow dung manure (CM) > poultry manure + cow dung manure (PM + CM) > poultry manure + saw dust manure (PM + SM) > saw dust manure (SM) for all levels of crude oil pollution (Fig. 1). Bioremediation of crude oil polluted soils is a promising treatment method that has been proven to maintain the soil integrity by improving its fertility (Graj et al. 2013; Silva-Castro et al. 2015; Hamoudi-Belarbi et al. 2018). The use of organic manures for the reclamation of crude oil polluted soil has recently evoked interest due to their bio-stimulatory effects on the growth of hydrocarbon-degrading microorganisms (Abdulsalam and Omale 2009; Graj et al. 2013; Silva-Castro et al. 2015; Nwogu et al. 2015). In this study, crude oil pollution drastically affected germination of *Zea mays* L. Similar results have been reported (Onuh et al. 2008a, b; Hamoudi-Belarbi et al. 2018). This could be attributed to the fact that crude oil pollution impaired free flow of air (oxygen) into the soil (reduced aeration), and also suppressed the activities of microorganisms that would have helped in the degradation and removal of substances inhibiting seed germination (Basra et al. 2006). This could also be due to the adverse effects of crude oil on the microorganism involved in the mineralization of organic materials which reduces some of the phytotoxic effect of the crude oil on the seeds (Okolo et al. 2005).

Amendments of crude oil polluted soil with different organic manures positively influenced the rate of germination of *Zea mays* L. (Fig. 1). Different organic manures affected the germination of the seeds in different ways. This implies that the constituent of the various manures is the actual determining factor in their bioremediation potentials. These differences in the bioremediation potentials of organic manures have been reported by several researchers (Christo et al. 2008; Madukwe et al. 2008; Ayolagha and Peter 2013). The effectiveness in the bioremediation potential of poultry manure as observed in this study may be attributed to the differences in the microbial composition and load of poultry manure compared to other organic manures used in the study (Ofoegbu et al. 2015; Alotaibi et al. 2018). Lower percentage germination observed with the application of sawdust manure may be attributed to low microbial activities associated with sawdust manure and high level of organic carbon (Offor and Akonye 2006; Obasi et al. 2013) which will impair the mineralization during compositing of the manure. Addition of poultry manure to cow dung or sawdust manure greatly improved their bioremediation potentials as reflected in the percentage of seed germination in this study (Fig. 1) with cow dung + saw dust producing the best. Combining these manures improves their bioremediation potentials due to the fact that the microbial consortium from the various organic manure sources may work in synergy to improve bio-stimulation and composting which is necessary to increase the microbial load in the crude oil polluted soil and hence the rate of degradation of the crude oil hydrocarbons by microorganism. The combined effects of microorganisms in the bioremediation of crude oil polluted soils have been documented (Nwogu et al. 2015; Hamoudi-Belarbi et al. 2018).

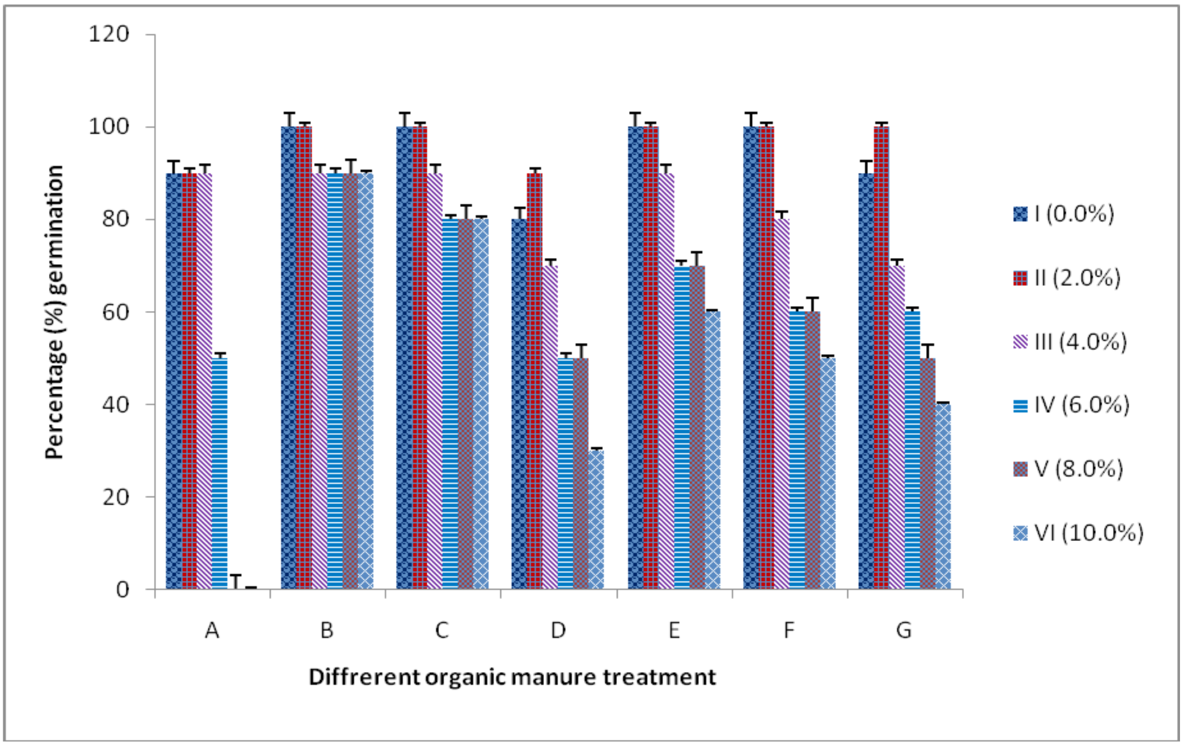

Fig. 1 Effects of different organic manure amendment on percentage (%) germination of *Zea mays* L. in varying degree of crude oil polluted soil

A (I-VI) = Pollution with no remediation treatment, B(I-VI) = Different pollution levels treated with 1.67 kg poultry manure (PM), C(I-VI) = Different pollution levels treated with 1.67 kg cow dung manure (CM), D(I-VI) = Different pollution levels treated with 1.67 kg saw dust manure (SM), E(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg cow dung manure (CM), F(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg saw dust manure (SM), G(I-VI) = Different pollution levels treated with 0.83kg cow dung manure (CM) and 0.83kg saw dust manure (SM).

The effects of different organic manure amendment in the plant height of *Zea mays* L. in varying degree of crude oil polluted soil for different weeks after planting (WAP) is shown in Fig. 2 (P, Q, R and S). The results showed that crude oil pollution significantly decreased ($P < 0.05$) the growth of *Zea mays* L. in a concentration-dependent manner. However, the study showed that application of different organic manures to the crude oil polluted soil significantly increased ($P < 0.05$) the growth height of *Zea mays* L. in the different weeks recorded after planting (WAP). Two weeks after planting (Fig. 2 P), the results showed that at all levels of crude oil pollution, tallest *Zea mays* L. (maize) plant were obtained in crude oil polluted soil amended with combined poultry manure + sawdust manure (PM + SM) followed by combined poultry manure + cow dung manure (PM + CM) and least in sawdust manure (SM). For four, six and eight weeks after planting, combined cow dung + sawdust manure (CM + SM) gave tallest *Zea mays* L plant while sawdust manure gave the shortest maize plant. There were significant differences ($P < 0.05$) in the height of maize grown under similar conditions of crude oil polluted soil amended with different organic manures (Fig. 2). Crude oil pollution affects the growth and yield of crops (Agbogidi and Nweke 2005; Aboh and Isitekhale 2013). This is due to the fact that the crude oil pollution changes the physicochemical properties of soil environment and the natural ecosystem making them undesirable for soil-nutrient transfers to plants (Bejarano and Michel 2010; Ezeonu 2010). The pollution of the soil with crude oil in this study adversely affected the growth of maize plant, especially at the early stages of two weeks after planting (2WAP) and the effect increased at the concentrations of crude oil pollution increased (Fig 2). Similar observations that demonstrated the retardation in the growth of plant seedlings in crude oil polluted soil have been reported (Ogboghodo et al. 2001; Onuh et al. 2008a, b). In this study, at four, six and eight weeks after planting (Fig. 2Q, R and S), the growth of maize seedlings improved especially at lower concentrations of crude oil pollution. This may be attributed to the fact that soil microbes present in the organic manures may have acclimatized and undergone modification suitable for the microbial degradation and mineralization of the crude oil compounds (Amakiri and Onefeghara 1983; Okolo et al. 2005; Graj et al. 2013). The time-dependent improvement in the growth of maize seedling depicted the level of microbial restoration of the crude oil polluted soils which directly reflected in the type of organic manure used for the amendment. Similar reports have been documented for other plants such as cowpea grown in crude oil polluted organic manure amended soil (Christo et al. 2008; Madukwe et al. 2008; Onuh et al. 2008a, b).

The results of different organic manures amendment on *Zea mays* L. leaf growth and development characteristics in varying degree of crude oil polluted soil is shown in Table 2. The results showed that the average number of *Zea mays* L. leaves and leaf area significantly decreased ($P < 0.05$) as the concentration of crude oil pollution increased but significantly increased ($P < 0.05$) in crude oil polluted soil amended with different manures throughout the growth (weeks after planting) period. Generally, the results indicated that leaf growth and development characteristics were greatly enhanced in crude oil polluted soil amended with a combination of organic manure treatment compared to those treated with single organic manure (Table 2). Similar results have been reported for other plants grown in crude oil polluted soil but amended with different organic and inorganic fertilizers (Offor and Akonye 2006). The improvement recorded in the crude oil polluted soils amended with organic manures could be attributed to the mineralization of the essential nutrients available in the soil for the growth of the plant by the different amendment options (Onweremadu and Duruigbo 2007). Treatment of crude oil polluted soil with organic manures bio-remediates the soil by increasing the microbial load which in turn increases the rate of degradation of the crude oil hydrocarbons (Njoku et al. 2009). The fertility of the amended soils is also greatly improved since organic manures not only reduce or eliminated the crude oil but also add nutrient to the soil and improves it aeration (Odokuma and Ibor 2002). Increase in leaf area caused by the various organic manures amendment options is an indirect reflection of increased photosynthesis and hence increased crop yield (Christo et al. 2008; Ayolagha and Peter 2013).

Sawdust manure (SM) treatment exerted a profound adverse effect on maize plant growth and development characteristics because during the study, it was observed that after the six weeks of planting (6WAP), maize plants in the crude oil polluted soil treated with sawdust were experiencing die-back and chlorosis of the leaves. Amakiri and Onofeghara (1983) observed that crude oil pollution produces similar effects on crop growth and development while Asuquo et al. (2010) reported that inefficient amendment of crude oil pollution with organic manure result to die back and chlorosis of the leaf during the growth period after planting (WAP). This observed adverse effect of crude oil polluted soil ineffectively amended with sawdust manure may be attributed to nutrient imbalance and the dehydrating effect of crude oil on maize seedlings, which sawdust manure treatment alone could not ameliorate (Udo and Fayemi 1975; Offor and Akoye 2006; Obasi et al. 2013). This study, however, showed that the ability of sawdust to ameliorate crude oil pollution for optimum plant growth and performance was improved greatly by combining sawdust manure with other organic manures. The combination of sawdust manure with poultry manure greatly improved the growth and development of maize seedling followed by its combination with cow dung manure. Combining poultry or cow dung manure with sawdust manure may have improved the microbial load and hence its bioremediation capabilities. Similar reports supported these findings (Das and Chandran 2011; Graj et al. 2013). The fact that combining these organic manures greatly improved their crude oil

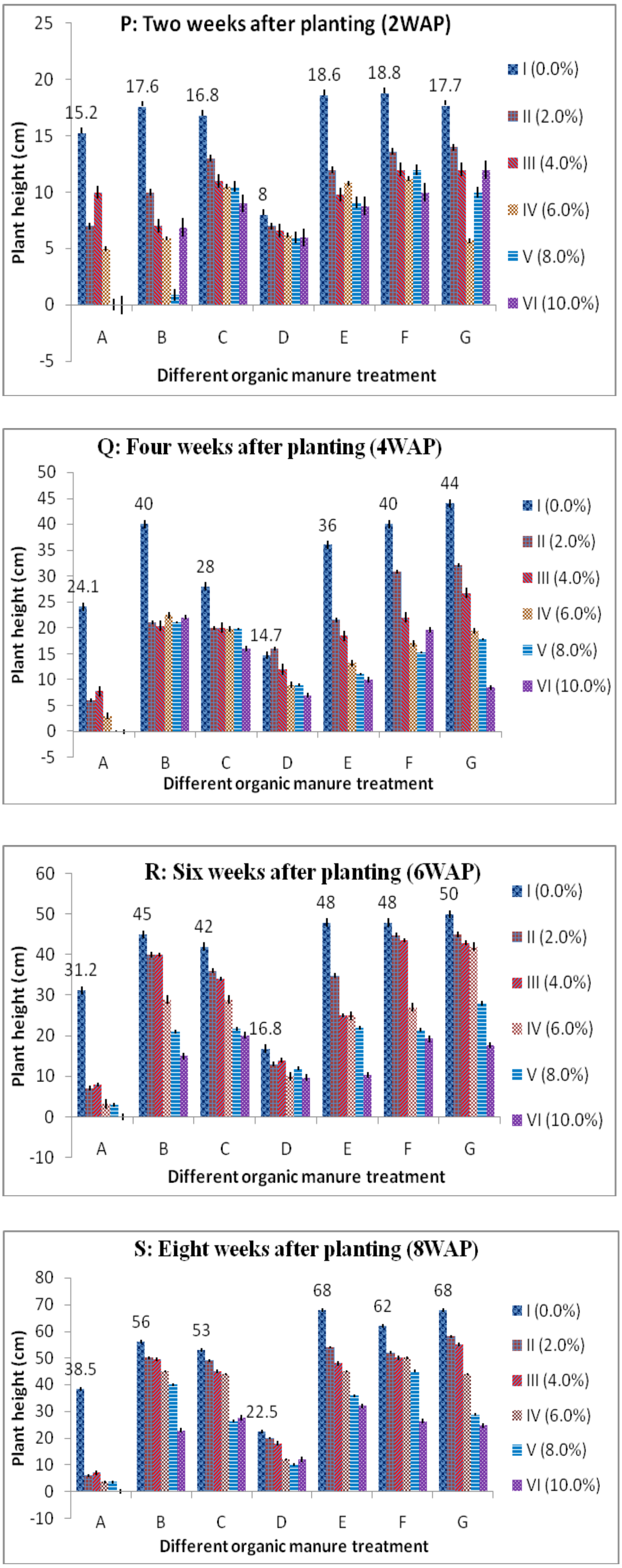

Fig. 2 Effects of different organic manure amendment on the growth height of *Zeamays* L. in varying degree of crude oil polluted soil

A (I-VI) = Pollution with no remediation treatment, B(I-VI) = Different pollution levels treated with 1.67 kg poultry manure (PM), C(I-VI) = Different pollution levels treated with 1.67 kg cow dung manure (CM), D(I-VI) = Different pollution levels treated with 1.67 kg saw dust manure (SM), E(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg cow dung manure (CM), F(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg saw dust manure (SM), G(I-VI) = Different pollution levels treated with 0.83kg cow dung manure (CM) and 0.83kg saw dust manure (SM).

Table 2 Effects of different organic manure amendment on *Zea mays* L. leaf growth and development characteristics in varying degree of crude oil polluted soil

Level of pollution		I (0.0%)		II (2.0%)		III (4.0%)		IV (6.0%)		V (8.0%)		VI (10.0%)	
Growth parameters		No. of leaves	Leaf area (cm^2)	No. of leaves	Leaf area (cm^2)	No. of leaves	Leaf area (cm^2)	No. of leaves	Leaf area (cm^2)	No. of leaves	Leaf area (cm^2)	No. of leaves	Leaf area (cm^2)
Two weeks after planting (2WAP)	A	5	53.38	5	26.2	5	18.0	3	13.0	0	0.0	0	0.0
	B	5	46.8	6	38.0	6	30.8	4	23.1	4	19.1	4	18.4
	C	6	56.0	5	48.5	6	40.2	6	40.0	5	37.0	5	32.0
	D	5	13.8	5	16.5	5	16.4	5	16.6	5	14.3	4	9.9
	E	5	93.0	6	50.5	6	39.4	4	26.8	5	26.8	6	24.8
	F	5	100.0	5	37.0	6	29.0	5	20.8	6	20.9	6	18.4
	G	7	54.0	6	56.0	6	48.2	5	36.8	5	35.6	5	26.6
Four weeks after planting (4WAP)	A	6	173.8	4	19.6	4	13.2	3	6.8	0	0.0	0	0.0
	B	8	262.0	7	163.0	8	129.0	8	129.0	8	94.0	7	73.4
	C	7	206.0	8	193.0	8	188.0	8	124.0	8	68.1	8	59.0
	D	5	48.0	5	35.5	6	22.9	4	21.0	7	20.9	5	10.8
	E	7	211.0	7	93.9	7	24.9	6	33.7	5	30.8	5	82.2
	F	8	280.0	7	196.0	8	101.0	7	45.0	6	30.6	5	33.2
	G	7	268.0	7	232.0	8	120.0	8	48.7	6	99.0	5	20.9
Six weeks after planting (6WAP)	A	9	270.6	4	9.8	5	13.2	4	8.3	4	10.5	0	0.0
	B	10	281.5	8	261.6	9	185.9	8	206.1	8	59.0	6	149.0
	C	7	203.0	8	193.0	8	194.0	10	188.0	8	120.0	8	116.0
	D	11	52.0	5	24.4	5	33.7	5	22.3	6	18.8	7	27.8
	E	10	436.0	9	241.0	7	97.0	6	123.0	7	105.0	6	136.0
	F	10	320.5	10	200.5	9	241.0	9	183.9	8	133.4	6	83.4
	G	10	282.5	9	244.4	9	201.1	9	244.4	7	301.7	7	72.6
Eight weeks after planting (8WAP)	A	10	312.0	4	19.6	5	12.0	4	9.3	4	11.0	0	0.0
	B	11	402.0	10	357.0	10	337.0	7	199.0	5	262.0	8	181.0
	C	7	435.0	8	323.0	9	186.0	10	207.0	9	226.0	8	122.0
	D	11	25.0	6	87.0	6	77.1	5	10.0	6	49.0	6	30.0
	E	11	462.0	11	435.1	11	183.5	7	72.5	9	358.3	9	173.9
	F	11	442.0	8	300.0	10	338.0	9	171.0	8	282.0	6	102.0
	G	11	355.5	11	320.6	10	223.3	10	267.8	7	129.0	7	113.0

A (I-VI) = Pollution with no remediation treatment, B(I-VI) = Different pollution levels treated with 1.67 kg poultry manure (PM), C(I-VI) = Different pollution levels treated with 1.67 kg cow dung manure (CM), D(I-VI) = Different pollution levels treated with 1.67 kg saw dust manure (SM), E(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg cow dung manure (CM), F(I-VI) = Different pollution levels treated with 0.83kg poultry manure (PM) and 0.83kg saw dust manure (SM), G(I-VI) = Different pollution levels treated with 0.83kg cow dung manure (CM) and 0.83kg saw dust manure (SM)

bioremediation potentials and their ability to support *Zea mays* L. growth and development characteristics showed that they contain different species of microbial loads and nutrients which may be more bioavailable to plants if they are allowed to interact (Burd et al. 2000; Obasi et al. 2013). Similar results have been reported when a combined microbial consortium or organic and inorganic fertilizers are used for crude oil remediation (Abdulsalam and Omale 2009; Das and Chandran 2011; Graj et al. 2013; Silva-Castro et al. 2015). In general, the study revealed that crude oil pollution impairs the growth and development of maize; amendment of crude oil polluted soil with organic manures especially combined organic manures significantly improved maize growth and development and hence its production in organic manure reclaimed soils.

Conclusion

The study revealed that crude oil pollution impacted negatively on soil and adversely affects the growth and development of maize (*Zea mays* L.) in a dose dependent manner; the higher the dose, the greater the negative impact on soil. It was also discovered that different organic manures have varying potentials in the amendment of crude oil polluted soils. The study showed that combination of organic manures especially cow dung + saw dust improved their crude oil remediation abilities and enhanced growth and development of *Zea mays* L. more than other combinations and single organic manure amendment options. This study has shown that sawdust waste could be made to support crop growth and development and hence crop production by combining them in appropriate quantities with other suitable organic waste especially cow dung to form good quality organic compost manure. The study recommends reconstitution of different organic waste to obtain good quality compost and their use for environmentally friendly bioremediation of crude oil polluted soils. Current research should focus on best ways of harnessing recalcitrant organic waste like sawdust for eco-friendly bioremediation and improvement in crop production since they are usually generated in very large quantities against the usual practice of burning them.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

Reference

Abdulsalam S, Omale AB (2009) Comparison of biostimulation and bioaugmentation techniques for the remediation of used motor oil contaminated soil. Braz. Arch. Biol. Technol 52(3): 747-754. https://doi.org/ 10.1590 /S1516 - 89132009000300027

Aboh SI, Isitekhale HHE (2013) Remediation of crude oil polluted soils: Effect of organic and inorganic nutrient source on the performance of sweet potato. African Crop Science Society 11: 767-772

Adedokun OM, Ataga AE (2007) Effects of amendments and bioaugmentation of soil polluted with crude oil, automotive gasoline oil and spent engine oil on the growth of cowpea (*Vigna unguiculata.*). Sci Res Essay 2(5): 147-149

Agarry SE, Owabor CN, Yusuf RO (2010) Bioremediation of soil artificially contaminated with petroleum hydrocarbon oil mixtures: Evaluation of the use of animal manure and chemical fertilizer. Bioremed J 14 (4): 189-195. https://doi.org/10.1080/10889868.2010.514965

Agbogidi OM, Nweke FU (2005) Effects of crude oil polluted soil on the performance of okra *(Abelmoschus esculentus*) Moench in Delta State. Afr. J. Nat. Sci 8: 31-35

Alotaibi HS, Usman AR, Abduljabbar AS, Ok YS, Al-Faraj AI, Sallam AS, Al-Wabel MI (2018) Carbon mineralization and biochemical effects of short-term wheat straw in crude oil contaminated sandy soil. Appl Geochem 88: 276–287. https://doi.org/10.1016/j.apgeochem.2017.02.017

Amadi A, Uebari Y (1992) Use of poultry manure for amendment of oil polluted soils in relation to growth of maize (*Zea mays* L.). Environ Int 18(5): 521-527. https://doi.org/10.1016/0160-4120(92)90271-5

Amadi A, Samuel DA, Anthony N (1996) Chronic effects of oil spill on soil properties and microflora of a rainforest ecosystem in Nigeria. Water, Air and Soil pollution 86: 1-11. http://dx.doi.org/10.1007/BF00279142

Amakiri JO, Onofeghara FA (1983) Effect of crude oil pollution on the growth of *Zea mays, Abelmoschus esculentus* and *Capsicum frutescens*. Oil and Petrochem Pollution 1(3): 199-205. https://doi.org/10.1016/S0143-7127(83)90182-5

Asuquo FE, Ibanga IJ, Hungafa N (2010) Effects of Qua Iboe Crude oil contamination and growth of Okra (*Abeloschus escuntus* L.) and fluted pumpkin (*Telflaria occidentalis* L.). Proceedings of the 27th Annual Conference of the Soil Science Society of Nigeria (Nov. 5-9, 2010) University of Calabar, Nigeria. Pp 218-223

Ayolagha GA, Peter KD (2013) Effect of remediation on growth parameters, grain and dry matter yield of soybean (*Glycine max*) in crude oil polluted ultisols in Ogoni land, South Eastern Nigeria. African J Environ Sci Technol 7(2): 61-67

Baker KH, Herson D (1994) Microbiology and biodegradation. In: Baker KH and Herson D. (eds). Bioremediation. McGraw Hill Inc., New York, pp 9-60

Basra SMA, Farooq M, Afzal I, Hussain M (2006) Influence of osmo-priming on the germination and early seedling growth of coarse and fine rice. Int J Agric Biol 8(1):19-22

Bebeteidoh OL, Kometa S, Pazouki K, Norman R (2020) Sustained impact of the activities of local crude oil refiners on their host communities in Nigeria. Heliyon 6(6). https://doi.org/10.1016/j.heliyon.2020.e04000

Bejarano AC, Michel J (2010) Large-scale risk assessment of polycyclic aromatic hydrocarbons in shoreline sediments from Saudi Arabia: Environmental legacy after twelve years of the Gulf war oil spill. Environ Pollut 158(5): 1561–1569. https://doi.org/10.1016/j.envpol.2009.12.019

Burd GI, Glick BG, Glick BR (2000) Plant growth promoting bacteria that decrease heavy metal toxicity in plants. Can J Microbiol 46(3): 237-245. https://doi.org/10.1139/w99-143

Chikere BO, Chijioke-Osuji O (2006) Microbial diversity and physicochemical properties of a crude oil polluted soil, Nigeria. J Microbiol 20: 1039-1046

Chorom M, Sharifi HS, Motamedi H (2010) Bioremediation of a crude oil-polluted soil by application of fertilizers. Iran J Environ Health Sci Eng 7(4): 319-326

Christo IEC, Madukwe DK, Onuh MO (2008) Growth and yield of cowpea (*Vigna unguiculata*) as influenced by cultivar and organic manure source in the humid tropical environment. Int Sci Research J 1(1): 47-5

Cunningham CJ, Philip JC (2000) Comparison of biostimulation in ex-situ treatment of diesel contaminated soil. Land Contamin Reclam 8: 216-269

Das N, Chandran P (2011) Microbial degradation of petroleum hydrocarbon contaminants: An overview. Biotech Res Int. https://doi:10.4061/2011/941810

Demnerova K, Mackova M, Spevakova V, Beranova K, Kochankova L, Lovecka P, Ryslava E, Macek T (2005) Two approaches to biological decontamination of groundwater and soil polluted by aromatics-characterization of microbial population. Int Microbiol 8 (2): 205-211

Dowswell CR, Paliwal RL, Cantrell RP (1996) Maize in the third world, West View Press, Boulder, Colorado, pp 118-193

Ezeonu CS (2010) Impact of soluble metal salts and crude oil contaminants on water retention capacity of soil and protein content of *Zea mays*. Electronic J Environ, Agric Food Chem 9(5): 885-891

FAO (2002) World agriculture: Towards 2015/ 2030 summary report of Food and Agricultural Organization (FAO) Rome, Italy. http://www.fao.org/3/a-y3557e.pdf. Accessed 18 April 2020

Gbogidi OM, Eruotor PG, Akparobi SO, Nnaji GU (2007) Evaluation of crude oil contaminated soil on the mineral nutrient elements of maize (*Zea mays* L.). J Agron 6: 188-193

Graj W, Lisiecki P, Szulc A, Chrzanowski Ł, Wojtera-Kwiczor J (2013) Bioaugmentation with petroleum-degrading consortia has a selective growth-promoting impact on crop plants germinated in diesel oil-contaminated soil. Water Air Soil Pollut 224: 1–15. https://doi.org/10.1007/s11270-013-1676-0

Hamoudi-Belarbi L, Hamoudi S, Belkacemi K, Nouri L, Bendifallah L, Khodja M (2018) Bioremediation of polluted soil sites with crude oil hydrocarbons using carrot peel waste. Environments 5(124). https://doi:10.3390/environments5110124

Ijah UJJ, Safiyanu H, Abioye OP (2008) Comparative study of biodegradation of crude oil in soil amended with chicken droppings and NPK fertilizer. Sci World J 3(2): 63-67

Kerr AW, Hall HK, Kozub SA (2002) Doing statistics with SPSS. SAGE publications Ltd, London, pp. 163-174

Knabel DB, Federle TW, Mc Avoy DC, Vertal JR (1994) Effects of mineral and organic soil constituents on microbial mineralization of organic compounds in natural soil. Applied Environ Microbiol 60(12): 4500-4508. https://doi:10.1128/aem.60.12.4500-4508

Lee I, Kin OK, Chang Y, Bae B, Kim HH, Dack KH (2002) Heavy metal concentration and Enzyme activities in soil from a contaminated Korean shooting range. J Biosci Bioeng 94(5): 406-411. https://doi.org/10.1016/S1389-1723(02)80217-1

Liang Y, Zhang X, Wang J, Li G (2012) Spatial variations of hydrocarbon contamination and soil properties in oil exploring fields across China. J Hazard Mater 241–242: 371–378. https://doi.org/10.1016/j.jhazmat.2012.09.055

Lindstrom JE, Braddock JF (2002) Biodegradation of petroleum hydrocarbons at low temperature in the presence of the dispersant corexit 9500. Mar Pollut Bull 44 (8): 739-749. https://doi.org/10.1016/S0025-326X(02)00050-4

Madukwe DK, Christo IEC, Onuh MO (2008) Effect of organic manure and cowpea (*Vigna unquiculata* (L.) Walp) varieties on the chemical properties of the soil and root nodulation. Sci World J 3(1): 43-46

Njoku KL, Akinola MO, Oboh BO (2008) Growth and performance of *Glycine max* L. (Merrill) in crude oil contaminated soil augmented with cow dung. Nature Sci 6(1): 48-58

Njoku KL, Akinola MO, Oboh BO (2009) Phytoremediation of crude oil Contaminated soil: The effect of growth of Glycine max on the physico-chemistry and crude oil contents of soil. Nature Sci 7(12): 22-30

Nwogu TP, Azubuike CC, Ogugbue CJ (2015) Enhanced bioremediation of soil artificially contaminated with petroleum hydrocarbons after amendment with Capra aegagrus hircus (Goat) Manure. Biotechnol Res Int 2015: 1–7. https://doi.org/10.1155/2015/657349

Obasi NA, Eze E, Anyanwu DI, Okorie UC (2013) Effect of organic manures on the physiocochemical properties of crude oil polluted soils. African J Biochem Resear7(6): 67-75

Odokuma LO, Ibor MN (2002) Nitrogen fixing bacteria enhanced bioremediation of crude oil polluted soil. Glob J Pure Appl Sci 8(4): 455-468. https://doi.org/10.4314/gjpas.v8i4.15993

Odu CTI (2006) Environmental degradation, restoration of pollution sites: A lecture delivered during the 32nd world environmental day celebration at port harcourt, state government, Ministry of Environment at the Alfred Diete Spiff Civic Centre Moscow road on Monday 5th June, 2006, port harcourt Rivers state, Nigeria. Rivers State Environmental Book Series 2006: A124-A162

Offor US, Akonye LA (2006) Amendment of crude oil contaminated soil with sawdust and *Chromoleana* leaves for optimum plant protection. African J Biotechnol 5(9): 770-774

Ofoegbu RU, Momoh YOL, Nwaogazie IL (2015) Bioremediation of crude oil contaminated soil using organic and inorganic fertilizers. J Pet Environ Biotechnol 5: 198. https://doi:10.4172/2157-7463.1000198

Ogboghodo IA, Iruafa EK, Osenwota IO, Chokor JU (2001) An assessment of the effect of crude oil pollution on soil properties, germination and growth of maize. Proceedings of the 27th annual conf of the soil science society of Nigeria Nov 5th –9th, 2001, University of Calabar, Nigeria

Ogboghodo IA, Azenabor UF, Osemwota IO (2005) Amelioration of crude oil polluted soil with poultry manure and the effect on growth of maize and some soil properties. J Plant Nutr 28(1): 21-32. https://doi.org/10.1081/PLN-200042152

Okolo JC, Amadi EN, Odu CTI (2005) Effects of soil treatments containing poultry manure on crude oil degradation in a sandy loam soil. Appl Biol Environ Res 3(1): 47-53. http://dx.doi.org/10.15666/aeer/0301_047053

Okpokwasili GC, Odokuma LO (1990) Effect of salinity on biodegradation of oil spills dispersants. Waste Manag 10(2):

141-146. https://doi.org/10.1016/0956-053X(90)90118-5

Onuh MO, Madukwe DK, Ohia GU (2008a) Effects of poultry manure and cow dung on the physical and chemical properties of crude oil polluted soil. Sci World J 3(2): 45 –50

Onuh MO, Ohazurike NC, Maduekwe, DK (2008b) Interaction of crude oil and manure treatments and its effects on the agronomic characteristics of maize (*Zea mays* L). World J 3(2): 107-111

Onuha CI, Arinze AE, Ataga AE (2008) Evaluation of growth of some fungi in crude oil polluted environment. Global J Agric Sci 2(2): 1596-1603. https://doi.org/10.4314/gjass.v2i2.2210

Onweremadu EU, Duruigbo CE (2007) Assessment of Cd concentration of crude oil polluted arable soils. Int J Environ Sci Technol 4 (3): 409-412

Rasheed M, Ali H, Mahmood T (2004) Impact of nitrogen and sulfur application in growth and yield of maize (*Zea mays* L). J Res Sci 15(2): 153-157

Raski I, Smith RD, Salt DE (1997) Phytoremediation of metals: Using plants to remove pollutants from the environment. Current Opin Biotechnol 8(2): 221-226. https://doi.org/10.1016/S0958-1669(97)80106-1

Silva-Castro GA, Uad I, Rodríguez-Calvo A, González-López J, Calvo C (2015) Response of autochthonous microbiota of diesel polluted soils to land-farming treatments. Environ Res 137: 49–58. https://doi.org/10.1016/j.envres.2014.11.009

Udo EJ, Fayemi AAA (1975) The effect of oil pollution on germination, growth and nutrient uptake of corn. J Environ Qual 4: 537-540. https://doi.org/10.2134/jeq1975.00472425000400040023x