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Effect of nutrient amendments on the growth of garden egg (*solanum melongena*) in crude oil polluted wetland, Egbema, rivers state

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Abstract

The study investigated the effect of different nutrient amendments on the growth of garden egg (*Solanum melongena)* in crude oil polluted Orashi River wetland, in Egbema, Rivers State, Nigeria. The treatment of the wetland with different weights of organic and inorganic fertilizer took place on site and effects of remediation on plant growth parameters were monitored. Test plants (*Solanum melongena)* were planted, monitored and measurements taken at fortnightly intervals for twelve weeks. The plant growth parameters in the wetland were affected by heavy impaction with crude oil in both seasons, while that of lightly impaction encouraged plant growth performance. Poultry waste, amongst other amendment agents was the best nutrient supplement for remediating heavily crude oil polluted wetlands with plant growth parameters (plant height and leaf numbers) 50 ±0.09cm/ 36 ±0.04 and 31 ±0.89cm/ 23 ±0.05 in the rainy seasons for lightly and heavily polluted wetlands respectively, (which are 1.67/ 1.64 and 1.03/1.05 better than growth performance in the control (unpolluted wetland). This nutrient amendment is weight dependent as the least quantity receives the most shock. This study has shown that adverse effects caused by heavily crude oil impaction on plant growth performance could be remedied by the addition of appreciable quantity of organic nutrient supplements like poultry waste to boost plant growth performance through improved soil quality/ fertility.

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Introduction

Wetlands are lands between terrestrial and aquatic ecosystems and are periodically inundated or saturated with water (Mitsch and Gosselink, 2007). They are rich in soil nutrients producing good soil conditions that favour the growth of various vegetations. Wetlands rank among the most productive and valuable ecosystems in the world and perform numerous important functions like farming, groundwater recharge etc. They are generally rich in mineral salts due to water supply from the surroundings via runoff and/or ground water (Ogban *et al.,* 2011).

Wetlands are ecologically sensitive and vulnerable to human disturbances. When wetland is polluted, the ecosystem is altered, and agricultural activities are affected (Adedokun and Ataga, 2007). Wetlands contaminated with heavy crude oil impaction can create non-conducive life conditions in the soil, due to some inherent factors like poor aeration, immobilization of soil nutrients, loss of water-holding capacity, lowering of soil pH, and reduction in soil enzyme activities (Sathiya-Moorthi *et al.*, 2008; Achuba and Peretiemo-Clarke, 2008), as well as inhibitory effect on the nitrate and phosphate reductase activities of plants (Odjegba and Atebe, 2007).

Crude oil is naturally occurring, unrefined / unprocessed oil composed of hydrocarbon deposits found deep beneath the earth's surface. Crude oil has ranging viscosity and can vary in colour to various shades of black and yellow depending on its hydrocarbon composition. Crude oil can be refined to produce usable products such as gasoline, diesel and various forms of petrochemicals. Crude oil pollution is a threat to the environment and the remediation is a major challenge to environmental research (Chorom *et al.*, 2010). Contamination of soil by crude oil could lead to a depression of microbial density and activities (Ogbo, 2009; Amadi *et al.,* 1996).

In the case of relatively light crude oil contamination, it stimulates the soil biochemical processes such as organic matter decomposition, ammonification, nitrification, symbiotic and non-symbiotic nitrogen fixation and geochemical cycling of elements, which thereafter increases the number and activities of microorganisms (Amadi *et al.,* 1996).

Crude oil exploration and production (E&P) activities occur frequently in the natural wetlands of South-South Nigeria such as the Orashi wetlands in Egbema, Rivers State. Oil exploration and production (E&P) processes can contribute to the localized loadings of total petroleum hydrocarbons (TPH) in the environment through accidental spillage or oil leaks from producing wells, gathering lines, transportation lines and pits. Release of hydrocarbons into the environment whether accidentally or due to human activities is a major cause of soil pollution (Holliger *et al.*, 1997). Oil exploration and production (E&P) activities have multiple deleterious impacts on the wetland ecosystem. The adverse effect of crude oil on wetlands ranges from loss of vegetation to addition of toxic materials. Thus, wetland degradation in the South-South Nigeria resulting from oil exploration and production (E&P) activities has drawn national and regional attentions.

The soil remediation processes leading to the eventual removal of petroleum hydrocarbon pollutants from the environment involve the trio: physical, chemical, and biological alternatives (Das & Murkherjee, 2007). However, there are limitations to the full implementation of the physicochemical technologies which were considered to be expensive, environmentally un-friendly, complex, destructive to soil texture and characteristics, and finally do not always result in complete removal of pollutants (Ayotamuno *et al.*, 2006). Hence, a valuable alternative has been recognized (bioremediation) for the detoxification and removal of toxic substances. This alternative apart from seldom acceptance, is cost-effective, environmentally friendly, simple in technology, and conservative to soil texture and characteristics (Gogoi *et al.*, 2003). It employs the use of organisms (bacteria, fungi and plants) to efficiently degrade pollutants such as crude oil/ petroleum hydrocarbons and use them as source of carbon and energy. The specificity of the degradation process is related to the genetic potential of the microorganisms to utilize molecular oxygen in degrading hydrocarbons, to generate the intermediates that subsequently enter the general energy- yielding metabolic pathway of the cell (Ghazali *et al.*, 2004). Some bacteria are mobile and exhibit a chemotactic response, by sensing a contaminant and moving towards it, while other microbes like fungi grow in a filamentous form near the contaminant (Gogoi *et al.*, 2003).

In developing countries, inorganic fertilizer have been found to be insufficient for agriculture, l*et al*one for use in enhancing remediating activities in cleaning of oil spills through improvement of soil nutrients. This necessitated the search for cheaper and environmentally friendly options of enhancing petroleum hydrocarbon degradation. One of such is the use of poultry manure which acts as both bulking agents and bacterial biomass suppliers, facilitates aeration through small pores and increases the water-holding capacity of the soil, thus enhancing bioremediation (Pala *et al.*, 2006; Van Gestel *et al.*, 2001).

Orashi wetlands in Egbema are prone to crude oil and associated end-products contamination due to the exploration and production activities in the area by major oil companies like Shell Petroleum Development Company (SPDC), National Agip Oil Company (NAOC) etc. However, most studies on the effect of crude oil pollution and its bioremediation applications focus on uplands, while that of wetlands have received less attention. This research evaluates the effects of nutrient amendments on growth of garden egg (*Solanum melongena*) in crude oil polluted Orashi wetland, Egbema, Rivers State with presentable data to promulgate sustainable environmental control programmes.

Materials and methods

Study Area

The study area is Orashi River Wetland at Egbema in Ogba/Egbema/Ndoni Local Government Area (ONELGA) of Rivers State, in the South-South Geopolitical zone of Nigeria. Ogba/Egbema/Ndoni is a Local Government Area in Rivers State, with capital at Omoku. Egbema community is divided into two areas, one part in Ohaji/ Egbema Local Government Area of Imo State, while the other part is in Ogba/Egbema/Ndoni Local Government Area (ONELGA) of Rivers State. Egbema community has vast fertile land including wetlands for agriculture and wildlife, and most of their people are great farmers, hunters and fishermen with a rich cultural history. The rainy season begins from April and lasts until October with annual rainfall varying from 1,500mm to 2,200mm (60 to 80 inches). The dry season begins from November and runs through March with two months of Harmattan from late December to late February. The hottest months are between January and March. The community is 80.5km away from Port Harcourt city, the capital of Rivers State. The geographical coordinates are Latitude 4.7572222°, and Longitude 6.7502778°. The area is of tropical climatic conditions with rain forest features and an average annual temperature ranging between 25 - 35°C as lowest and highest values respectively. The soil type is clay mixed with silt.

Samples used in the study

The samples used include: soil samples (on site), Bonny Light Crude Oil, organic nutrient samples (poultry waste and sawdust ash), inorganic nutrient samples (NPK fertilizer) and plant seedlings (*Solanum melongena*). The Bonny Light Crude Oil was collected from Ebocha Oil Centre, in Egbema, Rivers State, Nigeria. The poultry waste and sawdust ash were obtained from Redemption farms, Nekede, and Njoku sawmill, Naze, Owerri, respectively while the inorganic fertilizer (NPK 15:15:15) of Gading Mas and Petro brand was bought from ADP Farms, Nekede, Owerri. Garden egg seedlings (*Solanum melongena*) were purchased from Eke Mmegbu market, Amakohia in Owerri, Imo State, Nigeria.

Experimental design

The study was carried out on site in rainy and dry season. The two separate plots of the wetland, measuring eighteen feet squared (18ftx18ft) each, at twelve (12) feet apart from each other. The plots were initially divided into three equal portions representing the three different nutrient amendments (poultry waste, sawdust ash and inorganic fertilizer). Thereafter, each portion was sub-divided into three equal parts to represent the three different kilogram weights of the amendment samples (1kg, 2kg and 3kg) with two feet length internal gap/ demarcation between each slot. Each of the two separate wetland plots measuring eighteen feet squared (18ftx18ft) each, were spilled with graded volumes (either 5 or 20 Liters) of crude oil to represent lightly and heavily polluted wetlands respectively. Control samples were not spilled with crude oil and were situated at adjacent extremes of the two wetland plots. The two experimental plots of wetland were cleared, prepared and spilled with crude oil, and were exposed to climatic elements (rain and sunlight) throughout the period of the study.

Plant growth parameters measurement

These include the plant height and leaf number. The plant height was measured from the surface of the soil to the tip of the plant using a meter rule. The leaf numbers were obtained by visual counting of the leaves. All the parameters were monitored and measured at fortnightly interval for twelve (12) weeks..

Data Analysis

ANOVA (analysis of variance) was employed in this work and used to assess the significance of the different nutrient supplements on plant growth parameters. Descriptive statistics in form of means and standard deviation and Duncan post hoc were also used to assess the data. The analyses were done using SPSS 16.

Results

The test plants (*Solanum melongena*) were observed with improved growth developments in the lightly polluted wetlands. These improved growth developments in the lightly polluted wetlands were better to that observed in the control (unpolluted wetlands) and these improved growth performance cuts across the different nutrient supplements administered with poultry waste (50 ±0.09cm/ 36 ±0.04) as the best amended nutrient supplement, followed by sawdust ash (42 ±0.06cm/ 36 ±0.34) and inorganic fertilizer (NPK) (40 ±0.13cm/ 29 ±0.32) in the remediated wetlands. Serious adverse effects were observed with the heavily polluted wetlands on the test plant growth parameters as follows; poultry waste (31 ±0.89cm/ 23 ±0.05), sawdust ash (26 ±0.25cm/ 19 ±0.07) and inorganic fertilizer (NPK) (24 ±0.04cm/ 17 ±0.17). It was only in the poultry waste amended wetlands of heavily polluted wetlands that remediation activities brought the amended soil better than control (unpolluted wetlands) towards the end of remediation. Although, the amendment agents performance are weight dependent. Other amendment agents used in this study were unable to fully remediate the heavily polluted wetlands except for poultry waste.

Table 1. Effects of poultry waste amendment on the leaf number of *Solanum melongena* growing in lightly crude oil-polluted Orashi wetland during rainy and dry seasons.

Time	*Rainy season*				*Dry season*			
(Weeks)	Control	1 kg	2 kg	3 kg	Control	1kg	2kg	3kg
2	10 ± 0.28^d	14 ± 0.10^c	15 ± 0.14^b	18 ± 0.04^a	7 ± 0.15^d	11 ± 0.84^c	12 ± 0.37^b	15 ± 0.15^a
4	12 ± 0.19^d	17 ± 0.03^c	19 ± 0.07^b	22 ± 0.18^a	9 ± 0.03^d	14 ± 0.37^c	16 ± 0.23^b	19 ± 0.10^a
6	17 ± 0.14^d	23 ± 0.26^c	25 ± 0.30^b	26 ± 0.15^a	14 ± 0.42^d	16 ± 0.43^c	21 ± 0.14^b	22 ± 0.16^a
8	19 ± 0.54^d	25 ± 0.15^c	29 ± 0.35^b	31 ± 0.20^a	16 ± 0.23^d	20 ± 0.06^c	26 ± 0.04^b	28 ± 0.22^a
10	20 ± 0.09^d	26 ± 0.10^c	29 ± 0.21^b	33 ± 0.32^a	17 ± 0.10^d	24 ± 0.17^c	28 ± 0.17^b	30 ± 0.30^a
12	22 ± 0.70^d	29 ± 0.30^c	32 ± 0.42^b	36 ± 0.04^a	21 ± 0.07^d	26 ± 0.12^c	29 ± 0.12^b	33 ± 0.13^a

Within rows and each season, values with the same letters are not significantly different.

Table 2. Effects of poultry waste amendment on the leaf number of *Solanum melongena* growing in heavily crude oil-polluted Orashi wetland during rainy and dry seasons.

Time (Weeks)	*Rainy season*				*Dry season*			
	Control	1 kg	2 kg	3 kg	Control	1kg	2kg	3kg
2	10 ± 0.28^{d}	7 ± 0.13^{c}	8 ± 0.10^{b}	9 ± 0.19^{a}	7 ± 0.15^{d}	4 ± 0.83^{c}	5 ± 0.08^{b}	6 ± 0.05^{a}
4	12 ± 0.19^{d}	9 ± 0.03^{c}	10 ± 0.17^{b}	11 ± 0.36^{a}	9 ± 0.03^{d}	6 ± 0.06^{c}	7 ± 0.13^{b}	8 ± 0.12^{a}
6	17 ± 0.14^{d}	12 ± 0.05^{c}	14 ± 0.30^{b}	17 ± 0.25^{a}	14 ± 0.42^{d}	9 ± 0.42^{c}	11 ± 0.05^{b}	13 ± 0.13^{a}
8	19 ± 0.54^{d}	14 ± 0.09^{c}	16 ± 0.53^{b}	19 ± 0.91^{a}	16 ± 0.23^{d}	11 ± 0.25^{c}	13 ± 0.05^{b}	16 ± 0.15^{a}
10	20 ± 0.09^{d}	16 ± 0.21^{c}	19 ± 0.60^{b}	20 ± 0.24^{a}	17 ± 0.10^{d}	14 ± 0.19^{c}	15 ± 0.04^{b}	17 ± 0.07^{a}
12	22 ± 0.70^{d}	18 ± 0.11^{c}	20 ± 0.13^{b}	23 ± 0.05^{a}	21 ± 0.07^{d}	16 ± 0.11^{c}	18 ± 0.14^{b}	22 ± 0.14^{a}

Within rows and each season, values with the same letters are not significantly different.

The effect of the pollution levels on plant heights (lightly and heavily crude oil polluted wetlands) and the amendment with different nutrient supplements are graphically shown in Figures 1- 4, while that of leaf numbers are presented in Tables 1-6. The percentage (%) inhibition of *Solanum melongena* growth at 12th week of treatment with varying amount of organic and inorganic fertilizer is shown in Table 7. Test plant (*Solanum melongena)* recorded marginal growth better than control (unpolluted wetlands) at 12th week of treatment in 3kg poultry waste amended heavily polluted wetlands, hence no growth inhibitions were observed (Table 7). It was observed vividly that lightly polluted wetlands of both seasons came out the best in the measured growth parameters (plant heights and leaf numbers), with that of the rainy season leading. Also, in evaluating the effect of addition of different nutrient supplements on the polluted wetlands, it was observed that polluted wetlands supplemented with poultry waste did best in the measured growth parameter in both seasons. This is followed by sawdust ash and inorganic fertilizer in that trend. Values of plant growth parameters increases as weeks of remediation progresses, with rainy season values better than that of the dry season. Statistical differences were observed between values obtained in the different amendment agents in both lightly and heavily polluted wetlands when compared with control (unpolluted wetlands).

Table 3. Effects of sawdust ash amendment on the leaf number of *Solanum melongena* growing in lightly crude oil-polluted Orashi wetland during rainy and dry seasons.

Time (Weeks)	*Rainy season*				*Dry season*			
	Control	1 kg	2 kg	3 kg	Control	1kg	2kg	3kg
2	10 ± 0.28^{d}	12 ± 0.03^{c}	13 ± 0.12^{b}	15 ± 0.34^{a}	7 ± 0.15^{d}	8 ± 0.04^{c}	10 ± 0.30^{b}	12 ± 0.10^{a}
4	12 ± 0.19^{d}	14 ± 0.07^{c}	16 ± 0.05^{b}	19 ± 0.48^{a}	9 ± 0.03^{d}	11 ± 0.07^{c}	13 ± 0.20^{b}	16 ± 0.11^{a}
6	17 ± 0.14^{d}	21 ± 0.21^{c}	23 ± 0.30^{b}	25 ± 0.45^{a}	14 ± 0.42^{d}	18 ± 0.13^{c}	20 ± 0.14^{b}	22 ± 0.13^{a}
8	19 ± 0.54^{d}	22 ± 0.14^{c}	25 ± 0.32^{b}	27 ± 0.60^{a}	16 ± 0.23^{d}	19 ± 0.26^{c}	22 ± 0.09^{b}	24 ± 0.20^{a}
10	20 ± 0.09^{d}	24 ± 0.15^{c}	26 ± 0.26^{b}	30 ± 0.12^{a}	17 ± 0.10^{d}	21 ± 0.07^{c}	23 ± 0.12^{b}	27 ± 0.33^{a}
12	22 ± 0.70^{d}	26 ± 0.30^{c}	29 ± 0.33^{b}	33 ± 0.34^{a}	21 ± 0.07^{d}	23 ± 0.10^{c}	26 ± 0.10^{b}	30 ± 0.55^{a}

Within rows and each season, values with the same letters are not significantly different.

Discussion

Crude oil as a natural oil has been discovered to adversely affect plant growth performance at heavy impaction as indicated in the results. The heavy impact of wetlands with crude oil creates non-conducive environment for the microbes and plants, which leads to reduced microbial activities and immobilization of essential wetland nutrients leading to poor plant growth performance (Sathiya-Moorthi *et al.*, 2008; Anoliefo and Edegbai, 2000). The impact of wetland with crude oil, at a considerable low volume, often known as light impaction will lead to increased decomposition of organic matter, which invariably transforms to increased plant growth and performance. Microorganisms have been known to be involved in soil nutrient releases and degradation of organic matter, and most of these microorganisms are aerobic microorganisms. The presence of crude oil in light impaction in wetlands triggers off the much needed decomposition activities, nitrification processes (fixing of nitrogen), and other geochemical cycling of elements (Amadi *et al.*, 1996).

Table 4. Effects of sawdust ash amendment on the leaf number of *Solanum melongena* growing in heavily crude oil-polluted Orashi wetland during rainy and dry seasons.

Time (Weeks)	*Rainy season*				*Dry season*			
	Control	1 kg	2 kg	3 kg	Control	1kg	2kg	3kg
2	10 ± 0.28^{d}	5 ± 0.10^{c}	7 ± 0.18^{b}	8 ± 0.10^{a}	7 ± 0.15^{d}	2 ± 0.41^{c}	4 ± 0.06^{b}	5 ± 0.89^{a}
4	12 ± 0.19^{d}	6 ± 0.08^{c}	8 ± 0.13^{b}	10 ± 0.33^{a}	9 ± 0.03^{d}	3 ± 0.07^{c}	5 ± 0.16^{b}	7 ± 0.18^{a}
6	17 ± 0.14^{d}	10 ± 0.25^{c}	12 ± 0.30^{b}	13 ± 0.27^{a}	14 ± 0.42^{d}	7 ± 0.34^{c}	9 ± 0.23^{b}	10 ± 0.63^{a}
8	19 ± 0.54^{d}	11 ± 0.19^{c}	13 ± 0.43^{b}	16 ± 0.90^{a}	16 ± 0.23^{d}	8 ± 0.52^{c}	10 ± 0.15^{b}	13 ± 0.05^{a}
10	20 ± 0.09^{d}	13 ± 0.11^{c}	15 ± 0.50^{b}	16 ± 0.20^{a}	17 ± 0.10 ^{d}	10 ±0.16^{c}	12 ± 0.44^{b}	14 ± 0.57^{a}
12	22 ± 0.70^{d}	15 ± 0.03^{c}	17 ± 0.22^{b}	19 ± 0.07^{a}	21 ± 0.07^{d}	12 ±0.71^{c}	14 ± 0.10^{b}	17 ± 0.24^{a}

Within rows and each season, values with the same letters are not significantly different.

Table 5. Effects of inorganic fertilizer (NPK) amendment on the leaf number of *Solanum melongena* growing in lightly crude oil-polluted Orashi wetland during rainy and dry seasons.

Time (Weeks)	*Rainy season*				*Dry season*			
	Control	1 kg	2 kg	3 kg	Control	1kg	2kg	3kg
2	10 ± 0.28^{d}	11 ± 0.33^{c}	12 ± 0.10^{b}	13 ± 0.37^{a}	7 ± 0.15^{d}	8 ± 0.03^{c}	9 ± 0.35^{b}	10 ± 0.17^{a}
4	12 ± 0.19^{d}	13 ± 0.17^{c}	15 ± 0.09^{b}	17 ± 0.40^{a}	9 ± 0.03^{d}	10 ± 0.67^{c}	12 ± 0.23^{b}	14 ± 0.14^{a}
6	17 ± 0.14^{d}	19 ± 0.11^{c}	21 ± 0.32^{b}	24 ± 0.11^{a}	14 ± 0.42^{d}	16 ± 0.33^{c}	18 ± 0.15^{b}	21 ± 0.16^{a}
8	19 ± 0.54^{d}	21 ± 0.54^{c}	23 ± 0.30^{b}	26 ± 0.28^{a}	16 ± 0.23^{d}	18 ± 0.46^{c}	20 ± 0.19^{b}	23 ± 0.25^{a}
10	20 ± 0.09^{d}	22 ± 0.14^{c}	24 ± 0.25^{b}	28 ± 0.10^{a}	17 ± 0.10^{d}	19 ± 0.57^{c}	21 ± 0.15^{b}	25 ± 0.35^{a}
12	22 ± 0.70^{d}	24 ± 0.31^{c}	25 ± 0.31^{b}	29 ± 0.32^{a}	21 ± 0.07^{d}	21 ± 0.17^{c}	22 ± 0.12^{b}	26 ± 0.51^{a}

Within rows and each season, values with the same letters are not significantly different.

The immobilization of essential plant nutrients (Atuanya, 1987), by heavy crude oil impaction, was clearly evidenced in this study on the poor plants growth parameters of the heavily polluted wetlands. Also, it was observed that the shock of distorted growth parameters were more on the heavily polluted wetlands, than in the lightly polluted wetlands. This is in agreement with the report of Sathiya-Moorthi *et al.*, (2008) that heavy impaction of soil with crude oil will always create non-conducive environment for microorganisms by immobilizing soil nutrient elements, and creating inherent poor aeration, lowering of soil pH, and reduction of various enzyme activities, thereby leaving the soil incapacitated to sustain plant growth and development.

Table 6. Effects of inorganic fertilizer (NPK) amendment on the leaf number of *Solanum melongena* growing in heavily crude oil-polluted Orashi wetland during rainy and dry seasons.

Time (Weeks)	*Rainy season*				*Dry season*			
	Control	1 kg	2 kg	3 kg	Control	1kg	2kg	3kg
2	10 ± 0.28^{d}	4 ± 0.14^{c}	6 ± 0.40^{b}	7 ± 0.56^{a}	7 ± 0.15^{d}	2 ± 0.45^{c}	3 ± 0.12^{b}	4 ± 0.83^{a}
4	12 ± 0.19^{d}	5 ± 0.04^{c}	7 ± 0.18^{b}	9 ± 0.30^{a}	9 ± 0.03^{d}	2 ± 0.09^{c}	4 ± 0.11^{b}	6 ± 0.16^{a}
6	17 ± 0.14^{d}	9 ± 0.23^{c}	11 ± 0.36^{b}	12 ± 0.37^{a}	14 ± 0.42^{d}	6 ± 0.37^{c}	8 ± 0.44^{b}	9 ± 0.64^{a}
8	19 ± 0.54^{d}	10 ± 0.60^{c}	12 ± 0.42^{b}	14 ± 0.40^{a}	16 ± 0.23^{d}	7 ± 0.56^{c}	9 ± 0.13^{b}	11 ± 0.05^{a}
10	20 ± 0.09^{d}	12 ± 0.14^{c}	14 ± 0.53^{b}	16 ± 0.60^{a}	17 ± 0.10^{d}	9 ± 0.19^{c}	11 ± 0.04^{b}	13 ± 0.37^{a}
12	22 ± 0.70^{d}	13 ± 0.07^{c}	15 ± 0.20^{b}	17 ± 0.17^{a}	21 ± 0.07^{d}	10 ± 0.41^{c}	13 ± 0.19^{b}	16 ± 0.25^{a}

Within rows and each season, values with the same letters are not significantly different.

However, it was observed in this study that at very low pollution levels (light impaction), crude oil could be degraded to supplement on the available soil nutrients, in support of improved plant growth and development. Nwaugo *et al.,* (2007) made a similar observation when they studied the effect of petroleum produced (formation) water and the induced changes in bacterial quality and soil enzymatic activities in a farmland.

Table 7. Inhibition (%) of *Solanum melongena* growth at 12th week of treatment with varying amount of organic and inorganic fertilizer.

Treatment	*Rainy Season*			*Dry Season*		
	1 kg	2 kg	3 kg	1kg	2kg	3kg
Heavily polluted (height)						
Poultry waste	16.67%	6.67%	Nil	18.52%	7.41%	Nil
Sawdust ash	33.33%	26.67%	13.33%	37.04%	33.33%	14.81%
NPK	40.00%	33.33%	20.00%	44.44%	33.33%	22.22%
Heavily polluted (leaf)						
Poultry waste	18.18%	9.09%	Nil	23.81%	14.29%	Nil
Sawdust ash	31.82%	22.73%	13.64%	42.86%	38.10%	19.05%
NPK	40.91%	31.82%	22.73%	52.38%	38.09%	23.81%

The reported adverse effect of crude oil on plant growth and development in the wetlands, resulting in poor soil fertility and unavailability of arable wetlands for agriculture was remedied with the treatment of polluted wetlands with soil amendment agents. These amendment agents will supplement on the available soil nutrients and water-holding capacity of the wetland. This is in agreement with the report of Agarry and Ogunleye, (2012) who observed an increase in crude oil biodegradation from the degradation of spent engine oil in soil using Box-Behnken design under response surface methodology (RSM) when NPK fertilizer, Tween 80 (non-ionic surfactant) and pig manure were used as nutrient supplements. These nutrient supplements encouraged the degrading activities of microbes and the subsequent mobilization of essential nutrient elements (nitrogen, phosphorus, potassium and oxygen) for uptake by the plants. These nutrients (nitrogen, phosphorus, potassium and oxygen) are essential for plant growth and development hence availability will lead to improved plant growth and development. This was evidenced in the plant height and number of leaves produced in this study by the test plant (*Solanum melongena*) in the amended wetlands (polluted wetlands).

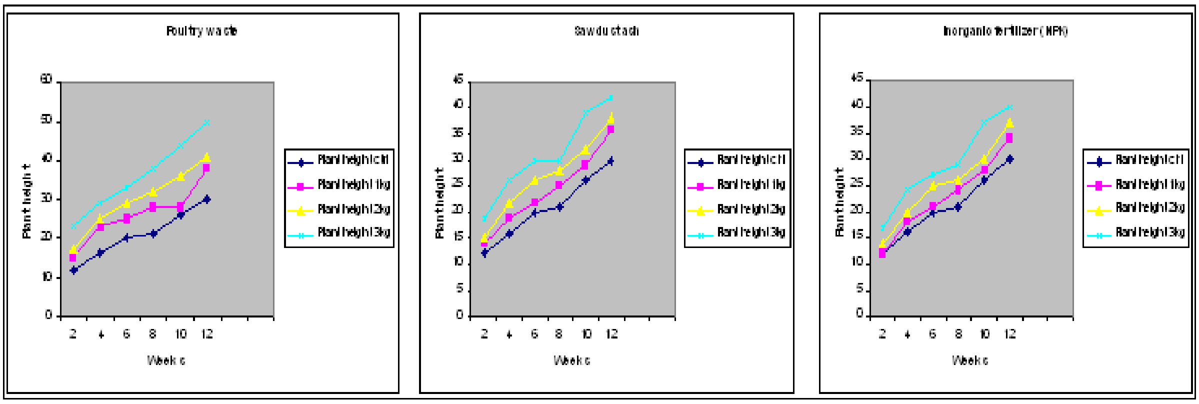

Fig. 1. Effect of lightly crude oil polluted Orashi wetland on plant height during rainy season with amendment samples viz Poultry waste, Sawdust ash and Inorganic fertilizer (NPK).

Plant growth parameters were best in lightly polluted wetlands, followed by control (unpolluted wetlands) and heavily polluted wetlands in that order. Results of growth parameters when compared, based on the three different amendment agents, revealed poultry waste to be the best, followed by sawdust ash and inorganic fertilizer in that order. When compared by seasons, plant growth parameters were best in the rainy season than in the dry season. Also, when growth parameters were compared on nutrient amendment weights, it was discovered that 3kgs weight of nutrient supplements did better than those of 2kgs and 1kg in that order. Further comparison on the degree of pollution, indicated that lightly crude oil polluted wetlands did best in plant growth parameters than control (unpolluted wetlands) and heavily crude oil polluted wetlands.

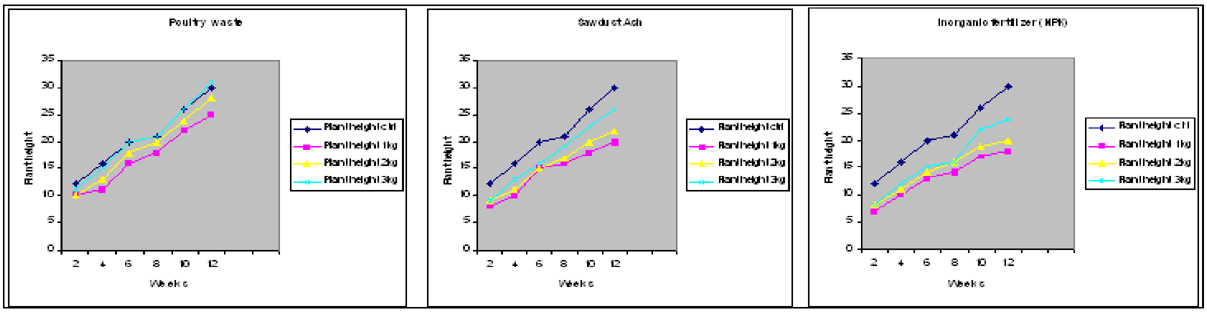

Fig. 2. Effect of heavily crude oil polluted Orashi wetland on plant height during rainy season with amendment samples viz Poultry waste, Sawdust ash and Inorganic fertilizer (NPK).

The addition of organic manure in this study has proved to be the best nutrient supplement in remediating activities of heavily crude oil polluted wetland, and effectiveness can be traced to the fact that it contains decomposed organic matter that can be absorbed directly by plants without further conversion. It helps in creating pores for aeration and equally harbors in large quantity, organic nitrogen and phosphorus sources that are already made and are easier to be utilized by both plants and microorganisms than their inorganic counterpart. In the case of nitrogen, organisms (plants and microbes) utilize the organic sources faster in preference to the inorganic forms, which will still have to be processed before it could be utilized (Nnamchi, 2010).

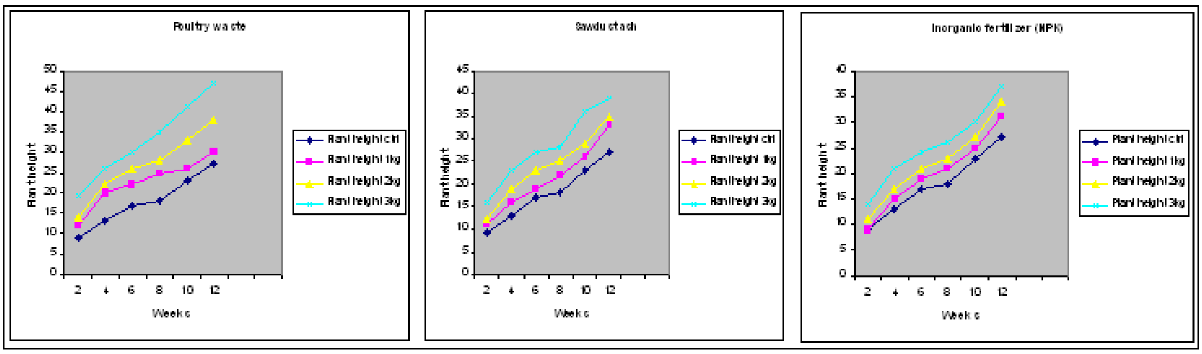

Fig. 3. Effect of lightly crude oil polluted Orashi wetland on plant height during dry season with amendment samples viz Poultry waste, Sawdust ash and Inorganic fertilizer (NPK).

The statistical comparison of the mean and standard deviation of the different nutrient supplements after ANOVA gave the choice selection of poultry waste as the best nutrient supplement in the remediation of crude oil polluted wetlands. This was possible because it shares the attributes of organic manure/ fertilizer. The plant growth results obtained in this study are in agreement with reports of Akujobi *et al*., (2011).

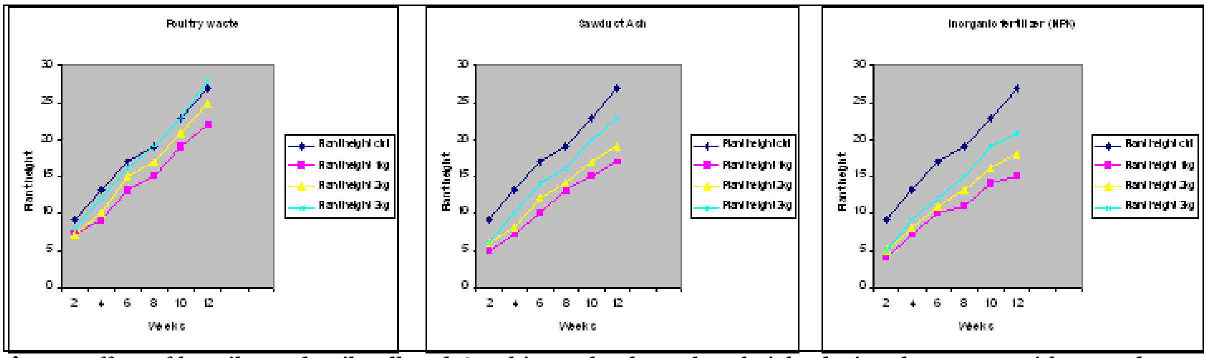

Fig. 4. Effect of heavily crude oil polluted Orashi wetland on plant height during dry season with amendment samples viz Poultry waste, Sawdust ash and Inorganic fertilizer (NPK).

The graphical representation of plant growth parameters among the different nutrient supplements shows that samples of the test plant (*Solanum melongena*) had the overall best growth performance in the lightly polluted wetlands of rainy season with plant height and leaf number – (50 ±0.09cm/ 36 ±0.04). This best growth performance in the rainy season was recorded in the 3kg poultry waste amended - lightly crude oil polluted wetlands at the twelfth (12) week. This growth performance of 3kg poultry waste (PW) in the rainy season, was followed by 3kg sawdust ash (SA) – amended wetlands (42 ±0.06cm/ 33 ±0.34), and finally by 3kg inorganic fertilizer (NPK) – amended wetlands (40 ±0.13cm/ 29 ±0.32). The least plant growth parameters (plant height and leaf number) of test plant were observed in the heavily crude oil polluted wetlands of dry season in the 1kg NPK – amended wetlands (4 ±0.83cm/ 2 ±0.45), followed by 1kg SA – amended wetlands (5 ±0.20cm/ 2 ±0.41), and finally by 1kg PW- amended wetlands (7 ±0.23cm/ 4 ±0.83). There was no growth inhibition at the 12th week in 3kg poultry waste amended heavily polluted wetlands. The highest inhibition percentage (plant height and leaf number) at 12th week was observed in 1kg NPK amended heavily polluted wetlands (44.44%/ 52.38%) while the least was in 1kg PW amended heavily polluted wetlands (16.67%/ 18.18%). The overall best growth performance observed with the test plant in lightly polluted wetlands attests to the report of Nwaugo *et al.,* (2011) that light impaction of petroleum produced water (PPW) into farmlands, increases soil quality (bioloads and enzymatic activities), as PPW could only cause adverse effects at heavy impaction on soil quality (bacterial spectrum and soil enzymatic activities).

It was deduced from the graphical representation that only poultry waste could remediate and restore heavily crude oil polluted wetlands for both seasons. Also, it was vividly observed that the higher the quantity of the nutrient supplements, the better the plant growth parameters in a heavily polluted wetlands. This simply means that the nutrient supplement performance is weight dependent. However, from detailed statistical analysis, involving ANOVA, poultry waste is the most recommended nutrient supplement for the remediation of heavily crude oil polluted wetlands.

Conclusion

In conclusion, it is advised that adverse effects caused by heavily crude oil impaction on wetlands against plant growth parameters could be remedied by the addition of appreciable quantity of organic nutrient supplements like poultry waste to boost plant growth performance with an improved soil quality/ fertility.

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