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Response of Maize (*Zea mays*) on Crude Oil Polluted Soil after One Month of Remediation with Spent Mushroom Substrate

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Authors' contributions

This work was carried out in collaboration among all authors. Author JAC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and bulk of the literature searches. Author GCI provided some data and few literature searches. Author OMA managed the analyses of the study, part of the literature searches and some part of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted to evaluate the influence of different levels of crude oil pollution remediated with spent mushroom substrate (SMS) on the growth of maize after one month of pollution. Composite soil samples randomly collected were polluted with Bonny light crude oil (v/w) at a concentration of 0%, 2%, 4% and 6% in a perforated plastic pots with 6 kg of top soil (0-20) cm. Ten percent of decomposed SMS was applied on each of the pots. A month after remediation, four seeds of Oba Super 11 maize variety were sown into each pot and later thinned to two after germination. The design was Complete Randomized Design consisting of six treatments and four replicates. After eight weeks of the study, results revealed a reduction in plant germination rate (60%) in polluted (SCM) against (87%) in non-polluted (SM) soil. Plant germination was highest (93.8%) on natural soil (SSM) amended with SMS. Amendment of the polluted soil with SMS improved the germination of the plant from 60% to 75%. There was a significant ($P<0.01$) decrease

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in plant height on polluted against natural soils. Amendment of the polluted soil with SMS slightly increased the height of the plant though not significant within the first six weeks of the study, however, a significant (P<0.01) increase was observed on the seventh and eighth weeks of the study. Pollution of the soil with crude oil revealed significant (P<0.01) reduction on some soil physico-chemical properties (available phosphorus, exchangeable cations (Ca, Mg and K), while a significant (P<0.01) increase was observed on total hydrocarbon content, total nitrogen, total organic carbon and total organic matter on the polluted over natural soil. Amendment of the polluted soil with SMS improved the nutrient status of the soil as there was significant (P<0.01) increase in the concentration of Ca, Mg, K, P and a reduction in the content of THC, TOC of the soil. Remediation of crude oil polluted soil, with spent mushroom substrate a month after pollution, improved soil fertility.

Keywords: Crude oil; pollution; concentration; amendment; spent mushroom substrate; Oba super 11 maize.

1. INTRODUCTION

Contamination of soil environment by petroleum hydrocarbon has become a major problem in most countries of the world possibly due to heavy dependence on petroleum by product as a major source of energy.

Crude oil contamination reduces the fertility status of the soil as most of the essential nutrients are no longer available for plant and crop utilization [1]. It also affects adversely the soil ecosystem through absorption to soil particles, provision of excess carbon that bring about nutrient imbalance and a reduction in soil nitrogen and phosphorus. These cause delay in natural rehabilitation of the polluted sites hence the need for remediation to improve the fertility of the soil.

Crude oil is a complex mixture of hydrocarbon used for the production of fuel and lubricant for transportation, a source of energy and a substrate for industry [2]. In spite of its numerous advantages, it can also cause a serious threat to the environment as a result of pollution resulting from oil spills due to illegal tapering of oil well heads, from storage tanks and illegal bunkering [3,4].

Spent mushroom (*Pleurotus ostreatus*) substrate (SMS) is a composited organic material remains after a mushroom crop has been harvested. Mike and David [5] reported that the substrate contains essential nutrients such as nitrogen, iron, manganese, copper and zinc though at a very low range 0.01 - 0.2 mg, sodium and higher amount of calcium and magnesium which neutralizes the sodium on the soil particles.

The SMS decomposes to form humus which play major role in the chemical behavior of several metals in soil through the humic acid contents thus enabling the metal to be retained in a complex and chelate forms [6]. Spent mushroom substrate is used in this study to remediate the crude oil polluted soil because it has strong pollutant catabolizing capacities which decreased pollutants in contaminated soil [7].

Maize (*Zea mays*) a test crop in this study is a major food crop with multifarious uses among farmers in Port Harcourt, Nigeria. Few studies have been done on the performance of maize on crude oil contaminated soil remediated with SMS, but information is inadequate about maize performance on soil after one month pollution and remediation with SMS.

Hence the study is aimed to evaluate the influence of different levels of crude oil pollution on the growth and performance of maize after one month of pollution.

2. MATERIALS AND METHODS

2.1 Site Description

The research was carried out at the Department of crop and soil science demonstration farm of University of Port Harcourt, Rivers State, Nigeria. The site is located at latitude 4°54'N and longitude 6°55'E at an elevation of 20 meter above sea level. The average temperature is 27°C with a relative humidity of 78% and an average annual rainfall between March and November that ranges from 2500 to 4000mm.

2.2 Source of Crude Oil

Fresh Nigerian Bonny light crude oil obtained from Shell Petroleum Company Nigeria limited, Bayelsa flow station at a concentration of 0, 2%, 4% and 6% representing 0 ml, 240 ml, 360 and 480 ml (v/w) respectively was used to pollute the soil in a perforated plastic pots filled with 6 kg of top soil (0-20) cm.

2.3 Amendment and Planting Materials

After polluting the soil with crude oil, ten (10) percent of total weight of polluted soil of decomposed spent mushroom substrate (SMS) was applied on each of the pots. One month after application of crude oil and spent mushroom substrate, four seeds of Oba Super 11 maize variety obtained from Agricultural Development Agency were sown into each pot and later thinned to two one week after germination [8].

2.4 Experimental Design

The design was a complete randomized design (CRD) consisting of six treatments; control 1: (soil + 2% crude oil contamination + maize = 2% SCM); control 2: (soil + maize = SM); SMS: (soil + maize + spent mushroom substrate); 2% SCMS: (soil + 2% crude oil contamination + maize + spent mushroom substrate); 4% SCMS: (soil + 4% crude oil contamination + maize + spent mushroom substrate); 6% SCMS: (soil + 6% crude oil contamination + maize + spent mushroom substrate). The treatment was replicated four times to see if there are more variability making a total of 24 pots. It was randomly sampled. Emerged weeds were removed by hand pulling and each pot was watered to field capacity on a daily basis.

2.5 Plant Data Collection

The plant germination percentage and height was recorded at weekly interval for a period of eight weeks. A meter rule was used to measure the plant height from the base at the soil surface to the leaf apex, while germination % was determined by visual observation.

2.6 Soil Sample Collection and Laboratory Analysis

A composite soil samples were collected from each of the pots, air-dried at room temperature, pulverized with pestle and mortar, sieved in a 2 mm mesh screen and sent to the laboratory for analysis for the following parameters:

Total organic carbon (TOC) by Walkley and Black [9] wet dichromate oxidation method [10], Total Nitrogen (TN) by Micro Kjeldahl digestion and distillation method [11], available phosphorus by Bray P-I method [12], while the phosphorus in the extract were measured by the blue color method [13]. Exchangeable cations (EC) Mg, Ca, K and N were extracted with neutral ammonium acetate, buffered at pH 7.0 and read using Flame Photometer [14]. Total hydrocarbon content (THC) was estimated using the method of Odu et al. [15]. Ten (10) g portion of the soil sample was shaken with 10 ml of carbon tetrachloride. THC was extracted and determined by the absorbance of the extract at 420 nm Spectrophotometer. Standard curve of the absorbance of the different known concentrations of equal amount of crude oil in the extract was first drawn after taking reading from the spectrometer.

2.7 Statistical Analysis

The data collected were analyzed using Analysis of Variance (ANOVA) procedure while the means were separated by the Least Significant differences LSD at 5% level of probability.

3. RESULTS AND DISCUSSION

Table 1 showed the effect of treatment on percentage germination of maize. An average of 60% of the plant germinated in control 1(soil contaminated with 2% crude oil- SCM) as against 87.5% in control 2 (natural soil with no crude oil-SM). Gill et al. [16], inferred that crude oil form hydrophobic layer over the root thus limiting absorption of water and nutrient to the plant. The reduction in plant germination in polluted against unpolluted soil could possibly be due to hydrophobic layer formed by crude oil over the plant root thus hindering water and nutrient uptake. This agrees with the report of Oyedeji et al. [17].

Plant germination was highest (93.8%) on natural soil amended with spent mushroom substrate (SSM). Improvement in plant germination from control 2 (natural soil 87.5%) with no spent mushroom substrate to 93.8% could be attributed to the presence of spent mushroom substrate applied into the soil. This agrees with the finding of [18,8].

Amendment of the soil contaminated with 2% crude oil with spent mushroom substrate (SMS) increased the percentage germination from 60% (2% SCM) to 75% (2% SCSM), implying that application of SMS to crude oil contaminated soil improved the percentage germination of the plants. The improvement in percent germination could possibly be due to some essential nutrients contained in SMS [19].

Increase in the level of crude oil concentration in the soil decreased the percentage germination. This tallies with the finding of Dariush et al. [20].

Generally, all the plants germinated in the different level of crude oil contamination. This is in contrast to the study of Oyedeji et al. [17] who reported no percentage germination on soil treated with 2% crude oil and maize and soil treated with 6% crude oil augmented with SMS. The reason for the contrast could possibly be due to one month period allowed after remediation for breakdown of crude oil components by micro-organisms before planting of the maize. The lowest level of maize germination (56.8%) was on soil contaminated with 6% of crude oil amended with SMS.

Effect of treatment on plant height is presented in Table 2. The result revealed significant (P<0.01) difference between control 1(SCM) and control 2 (SM) within the first seven days of maize growth, the trend was sustained through out the eight weeks of the study indicating that that contamination of the soil with crude oil decreased the plant height.

The reason for the reduction could possibly be attributed to anaerobic conditions prevalent in crude oil contaminated soil, insufficient aeration, increase in oxygen demand because of oil decomposing micro-organisms and interference with uptake of soil water by the root Ekundayo et al. [21].

There was slight increase in plant height, though not significant between control 1 (2% crude oil with no spent mushroom –SCM)) and soil contaminated with different levels of crude oil amended with spent mushroom substrate-(2%, 4% and 6% SCMS) within the first sixth weeks of the study, but at the seventh and eight week, significant (P<0.01) difference were observed. Similar report was observed by Merki and Schutze-Kraff [22] who attributed the significant difference to the decomposition of spent mushroom substrate releasing nutrients which are used as energy and cell development by petroleum utilizing micro-organisms.

A significant (P<0.01) difference was observed in plant height between soil contaminated with 2% crude oil amended with spent mushroom

Table 1. Effects of treatment on maize germination

Treatment	Percentage germination (%)
Control 1	60
Control 2	87.5
SSM	93.8
2% SCSM	75
4% SCSM	68.8
6% SCSM	56.8
LSD	2.42
P Value	<0.001

Control 1 = Soil + 2% crude oil + maize (SCM); Control 2 = Soil + maize (SM); SMS = Soil + Spent mushroom substrate + Maize; SCMS = Soil + Crude oil + Spent mushroom substrate + Maize

Table 2. Physico-chemical parameters of the soil after cultivation of the eight weeks maize plant

Treatment	Ca	K	Mg	Na	P	THC	TN	TOC	TOM
Control 1	0.51	0.71	0.31	0.05	20.60	20.0	0.35	4.11	7.06
Control 2	0.63	1.23	0.84	0.11	30.60	0.01	0.02	4.29	7.40
SMS	1.27	2.40	3.24	0.06	35.90	0.01	0.40	7.86	13.45
2% SCMS	0.19	1.89	0.94	0.32	10.30	7.50	0.16	3.61	5.72
4% SCMS	0.24	1.96	0.16	0.03	17.30	26.0	0.26	5.07	8.84
6% SCMS	0.39	0.84	0.68	0.06	23.30	40.03	0.26	5.12	8.74
LSD	0.143	0.14	0.13	0.04	0.17	0.84	0.06	0.65	0.09
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Control 1 = Soil +2% crude oil + maize; Control 2 = Soil + maize; SMS = Soil + Spent mushroom substrate + maize; SCSM = Soil + Crude oil + spent mushroom substrate + maize

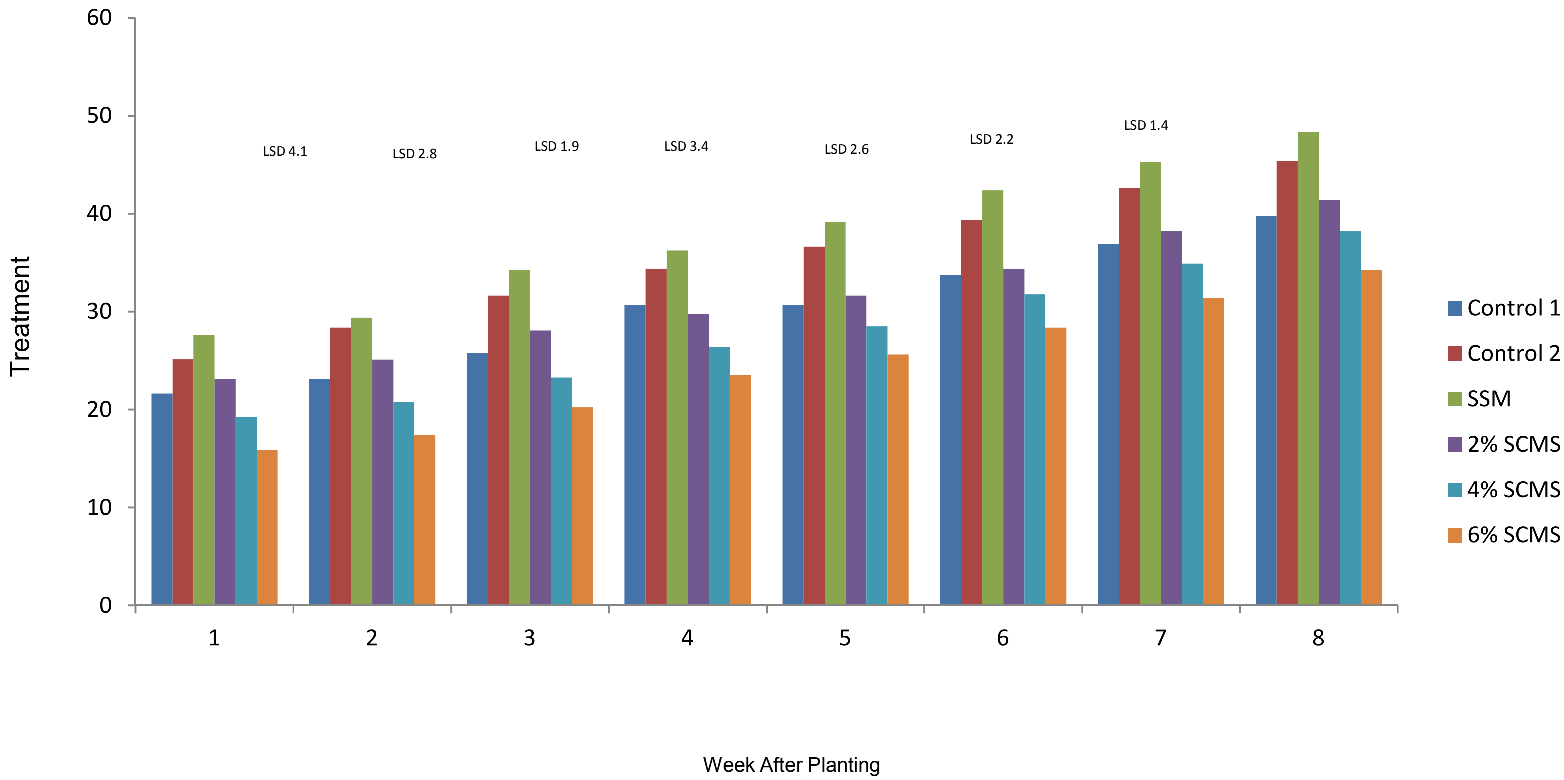

Fig. 1. Influence of maize height by treatments up to eight weeks after planting

Control 1= Soil + 2% crude oil + maize (SCM)
Control 2 = Soil + maize (SM)
SMS = Soil spent mushroom substrate + Maize
SCMS = Soil + crude oil + spent mushroom substrate + maize

substrate and soil contaminated with 6% crude oil amended with spent mushroom substrate indicating that the higher the concentration of crude oil in soil environment, the higher the adverse effect on plant growth.

Result of the study also showed that plant height decreased with increase in the level of crude oil concentrations. The progressive depression of plant height with increase in level of crude oil concentration could be due to the stress impose on the soil which may have interfered with water uptake and gaseous exchange thus leading to physiological drought [23].

The result of the study on physico-chemical properties of crude oil contaminated soil remediated with spent mushroom substrate is presented in Table 2.

Contamination of the soil with crude oil revealed a significant decrease ($P<0.01$) in available phosphorus, exchangeable cations (Ca, Mg and K) and a significant increase ($P<0.01$) on total hydrocarbon content (THC), total nitrogen, total organic carbon and total organic matter between contaminated and natural soil; implying that contamination of the soil with crude oil decrease the contents of Ca, Mg, K, Na, P and an increase in the concentration of THC, TN, TOC and TOM in the soil.

The increase in THC, TN and TOC in crude oil contaminated soil over natural soil corroborates with the findings of Ayolagha et al. [24] and Oyedeji et al. [17]. The increase in Total Nitrogen could be attributed to mineralization by micro-organisms during degradation of crude oil in the soil [25].

Percent total carbon in a soil gives an idea of the level of organic compound present in the soil as percent carbon (organic or inorganic), representing the extent of hydrocarbon in the soil. The greater the carbon content the higher the level of organic pollutants present [26]. The increase in Total organic carbon and Total organic matter could possibly be as a result of the carbon substrate which may have being added into the soil from crude oil.

The significant reduction ($P<0.01$) in concentrations of available phosphorus, exchangeable cations such as Ca, K, Mg; in contaminated over natural soil agrees with the report of [24,17]. Oyedele and Amoo [27], adduce that the reduction in value of NPK, Ca, Mg and Na in crude oil contaminated soil could possibly be due to the immobilization of these soil nutrients by crude oil. Crude oil make the soil hydrophobic causing limited water and air to be available for nutrient and mineral to dissolve in soil solution. Some of these nutrients may also have been trapped in the organic phase of the crude oil contaminated soil and so unavailable to the soil solution.

Amendment of the crude oil contaminated soil with spent mushroom substrate (SMS) improved the nutrient status of the soil as there was significant ($P<0.01$) increase in the level of concentration of Ca, Mg, K, and P and a reduction in the content of THC, TOC and TOM over the contaminated samples.

The increase in the concentration of P, N, K and Mg could be as a result of the high nutrient content pre sent in spent mushroom substrate [28], Oyedeji et al. [17]. These mineral nutrients (N,P,Ca and Mg) may have been mineralized by micro-organisms and thus contributed to the observed significant improvement in the soil properties. This agrees with the findings of Urunmtsoma et al. [29] and Akpoveta et al. [30].

The significant reduction in THC observed in the study after amendment of the soil with spent mushroom substrate could be due to the degrading action of micro-organisms that utilize hydrocarbon as energy source in their tissues. This is in line with the findings of Cook et al. [31] who observed a decrease in crude oil and an increase in soil recovery after a given time with the help of crude oil degrading organisms. The role of spent mushroom substrate in the reduction of total hydrocarbon contents of soil contaminated with spent automobile lubricant has earlier been reported Gbarakoro and Chukwumati [32].

Hutchinson et al. [33] reported that adequate fertilization is necessary for enhanced hydrocarbon degradation rates in polluted soil. The reason according to their observation was that adequate fertilization helped to reduce competition between plants and micro-organisms and so enhanced degradation. The higher the levels of crude oil concentration (2%SCMS, 4%SCMS and 6%SCMS), the higher the content of available phosphorus (10.30, 17.30 and 23.30 mg/kg), Total hydrocarbon content (7.50, 26.0 and 40.03 mg/kg) and Total organic carbon (3.61, 5.07 and 5.12%) respectively. This implies the higher the level of contaminants, the increase in the contents of THC, TOC and TN and a decrease in the contents of Ca, K and Na in the soil.

4. CONCLUSION

The remediation of crude oil polluted soil, with spent mushroom substrate (SMS) a month after pollution, improved soil nutrient contents as well as soil fertility thereby improving the germination and growth of maize.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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