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Use of Compost to Enhance the Growth of Tomatoes in Soil Contaminated with Nigerian Crude Oil

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Abstract: This laboratory study measured the growth of tomatoes (*Solanum lycopersicum)* in soils artificially contaminated with Bonny light crude oil at 5, 7.5 and 10% level (w/w). Tomatoes grown in nursery trays were supplemented with compost at a mix ratio of compost/soil 1:1 which is equivalent to 50% compost (w/w). The results showed that germination of seeds without the addition of compost was adversely affected by the oil pollution. In the controls (without oil), the highest biomass yield of 492 mg was recorded at 50% compost/soil and the lowest yield of 245 mg in soil only (without compost). However, there was total inhibition to growth at initial 10% oil level suggesting that 10% oil level is above the trigger level for plant growth. On addition of compost, contamination levels were diluted and plants grew in soil with the least diluted content of 5% oil level. The aboveground biomass yield was enhanced reaching 130±22, 55±9.8 and 39±36 mg at 2.5, 3.75 and 5% diluted oil concentrations, respectively.

Key words: Contaminated soil, Nigerian crude oil, tomatoes, compost, biomass yield, Niger Delta

INTRODUCTION

Activities associated with crude oil production, exploration, transportation and marketing have led to increased number of oil spills both on land and into water bodies. This high rate of oil spillage is a global concern due to the environmental degradation, resulting from it in recent years. This is the case in the Niger Delta region of Southern Nigeria. The region occupies approximately 7% of the land area of Nigeria and produces the bulk (nearly 85%) of the country's crude oil. Oil exploration and exploitation have led to land contamination and a reduction in the amount of arable land available to local farmers. Oil bunkering, a common business in the region involves drilling into oil delivery lines to extract crude oil which is subsequently loaded into tankers for onward sale to a racquet of buyers. This has led to pipeline damage, serious oil spills and pollution. The people of the Niger Delta are predominantly farmers and for every oil spill that occurs, the little arable land available kept on reducing thereby affecting their traditional source of livelihood.

The reuse of crude oil contaminated land for agricultural purposes has resulted in poor yields (Anoliefo and Vwioko, 1995; Nwachukwu, 2001). The situation that currently exists within the Niger Delta for the restoration of oil-contaminated land is rather *ad hoc* and there is no guidance provided for local farmers as to how to deal with such soil. Many researchers have investigated the use of combination of animal manure and mineral fertilizer as treatment for oil contaminated soils. Their findings showed that germination of seeds without the addition of organic amendments was adversely affected by the presence of the oil, suggesting that crude oil inhibited plant growth (Merkl *et al*., 2005; Njoku *et al*., 2008; Adekunle, 2011). Similarly, others have investigated environmental pollution in the Niger Delta and have reported significant changes in soil properties attributable to oil spillage (Antai, 1990; Adeniyi and Afolabi, 2002; Ijah and Antai, 2003; Osuji and Adesiyan, 2005; Sojinu *et al*., 2010). Such alteration of soil properties could re-shape agricultural productivity in the Niger Delta region of Nigeria and areas of similar context. It is thought that some mineral element could be limiting in oil contaminated soil. This deficiency in nutrients also causes stress to the plants (Merkl *et al*., 2005). Similarly, the effects of reduced oxygen on plants due to presence of hydrocarbons in crude oil contaminated soil has been investigated (Osuji and Nwoye, 2007). This effect is an increase in the utilization of other available electron acceptors such as nitrate which adds to the reducing environment. The direct use of nitrates as electron acceptor might partly explain the reduction in nitrogen

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levels observed in crude oil contaminated soil. Since, nitrogen is the major building blocks used by plants for cell synthesis, any reduction in available nitrogen poses a stress on the plants and affects their yield.

In Nigeria, there is abundance of food wastes particularly during the harvesting period. This arises because the local farmers do not have a means of preserving their produce for longer periods. Thus after the harvest, fruits and vegetables rot away and are disposed of in dumpsites. In addition to this, many of the public abattoirs have no proper disposal routes and as a result, animal wastes end up in open dumps. The wastes are left to decompose in the open and sometimes are burnt in an uncontrolled manner releasing noxious gases into the environment. The use of compost is seen as a viable option in Nigeria because the raw materials are available locally and composting does not involve sophisticated technology. An estimate of the daily volume of waste generated in Port Harcourt, the hub of the Niger Delta region is 8781.25 m^3 of which 60% is organic fraction and can be used as composting material (Igoni *et al.*, 2007).

This study investigates the effect of adding compost to crude oil contaminated soil and its effect on the productivity of tomatoes in such soil. Tomatoes are popular vegetables used globally in preparing different dishes especially in the Niger Delta where it is used mainly to prepare rice, a stable food in the region. The findings of the study can inform better ways of treating contaminated soils and making them useful for agricultural purposes.

MATERIALS AND METHODS

Materials: The soil used in this experiment was agricultural topsoil (150 mm) obtained from northern England. This soil had not been previously exposed to oil contamination. The compost used was mature green waste compost (approximately 3 months old). The crude oil (pH 4.9) was obtained from Shell Petroleum Development Company (SPDC) Limited in Port Harcourt, Nigeria. The pH and electrical conductivity of the soil/compost extracts were determined according to standard methods (APHA, 1992). This was done using calibrated HQ 40d portable pH, conductivity meter manufactured by HACH U.S.A. The ratio of soil-water was 1:2. The characteristics of the materials used are shown in Table 1.

Treatments: One kilogram batch of soil was contaminated with Bonny light crude oil at 5, 7.5 and 10% (w/w) and thoroughly mixed i.e., 50, 75 and 100 g of oil/1000 g soil, respectively. Compost was added to half of the contaminated soil at the rate of 50% (w/w) i.e., compost/soil 1:1. The addition of compost diluted the contamination levels. The controls for the experiments were uncontaminated soil and uncontaminated compost/soil mixture. All the experimental conditions (Table 2) were set up in two replicates and monitoring was undertaken for 28 days.

Fig. 1: Plastic sheet covering the trays, removed after observing 70% germination in the controls

Table 1: Physico-chemical characteristics of soil and compost

Parameters	Soil	Compost
Moisture content (%)	26.0	34.0
Organic matter (%)	9.0	34.0
pH	7.4	8.4
Electrical conductivity (μS cm^{-1})	29.0	685.0

Table 2: Experimental design

Treatment	Details of treatment
1	Control 1-soils only
2	Control 2-compost/soil only (1:1)
3	Soil with oil at 5%
4	Soil with oil at 7.5%
5	Soil with oil at 10%
6	Compost/soil (1:1) with oil at 2.5%
7	Compost/soil (1:1) with oil at 3.75%
8	Compost/soil (1:1) with oil at 5%

This study monitored the germination potential of tomato seeds under different soil treatments by measuring indices such as seedling emergence, aboveground biomass yield (fresh weight) and shoot length. Each tray was filled with 500 g of the compost/soil mixture depending on the treatment and was moderately watered using distilled water while allowing any excess water to drain away. Eight tomato seeds were planted per tray and covered with opaque plastic which was removed as soon as 70% of the seedlings in the controls emerged (Fig. 1). The germination count and the number of seeds that survived were done at day 7, 14, 21 and 28. At the end of 28 days, the tomato plants were cut off the soil surface and the biomass (fresh weight) was measured using a weighing balance. The plant height was measured using a ruler.

RESULTS AND DISCUSSION

Effects of treatment on seed germination and growth: Figure 2 and 3 represent the germination and survival of *S. lycopersicum* over 28 days. The soil on its own (control 1) had higher number of survivals between day 14 and 21, after which the plants started dying off. Similar trend was observed for soil at 5% initial oil level. There was no germination at 7.5% initial oil level until day 14 while total inhibition to growth was observed at 10% initial oil level. The second control: Compost/soil 1:1 (Fig. 3) had highest number of seeds that survived until day 28.

The addition of compost at the rate of 50% to the initial oil levels reduced the contamination levels from 5, 7.5 and 10% to 2.5, 3.75 and 5% oil concentration, respectively. The highest oil dilution of 2.5% (Fig. 3) sustained more growth than other treatments until day 28. However, the least diluted oil content of 5% did not support germination until day 14. Thus, comparing the results at 2.5% diluted oil concentration to the initial 5% oil level, a higher number of seedlings survived until day 28 showing the beneficial effect from addition of compost to the contaminated soil. At 5 and 7.5% initial oil contamination, results show that as oil level increases, the number of seeds that survived were reducing.

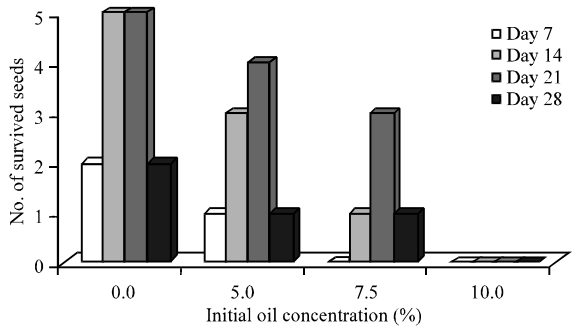

Fig. 2: No. of tomato seeds that survived in contaminated soil without compost

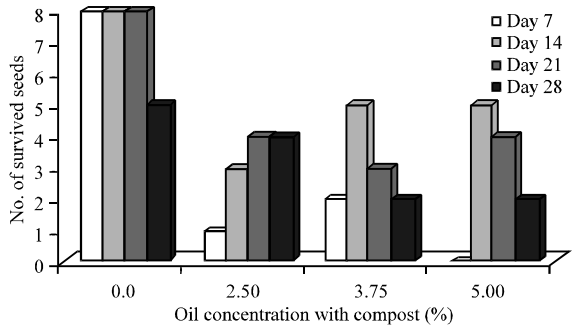

Fig. 3: No. of tomato seeds that survived in compost/soil mixtures with oil

The results show that germination of seeds without the addition of compost was adversely affected by the presence of the oil suggesting that crude oil inhibited plant growth. Visual observation revealed that the contaminated soils appeared waxy in appearance. This oily texture could limit the movement of gases and water into the soil (Adekunle, 2011). Perhaps, in crude oil contaminated soil, the pores are likely to be blocked by the oil thereby increasing the water stress on the seeds. Lack of water could make the soil hard and unsuitable for seed germination. In the present study, no growth was recorded at 10% oil level resulting in 100% growth inhibition. The result agrees with observations of other researchers (Ijah and Antai, 2003; Osuji and Adesiyan, 2005) that higher levels of oil contamination did not only delay germination but completely prevented germination. However, on the addition of compost, growth was observed for all the diluted oil concentrations even though growth was delayed at 5% least diluted oil concentration until day 14. It might be that the presence of crude oil produced inhibiting effects such as nutrient uptake and affected both seed germination and the microorganisms until after the lag phase when the microorganisms were able to utilize the oil as carbon substrate, as well as metabolizing them into the soil to improve its fertility and for plant use.

This demonstrates the potential of using compost as organic amendment for bioremediation of crude oil contaminated soil. The presence of great microbial diversity in compost compared to ordinary soil makes it a better bioremediation material (Adekunle *et al*., 2011). In addition, the growth of tomatoes in the treated compost/soil mixture suggests recovery of the contaminated soil for agriculture.

Plant height: Figure 4 represents the average plant height at the end of the 28 day planting period for both the soil and compost/soil mixtures at different oil levels. Higher plant height was recorded from the control trays in which there was no crude oil contamination. The uncontaminated soil produced a mean height of 4.1±0.63 cm and slightly higher height (4.8±0.91 cm) on addition of compost at the rate of 50%. However, plants exposed to initial 5 and 7.5% oil level without any form of treatment recorded a height of 3.2±0.52 cm and 2.2±0.71 cm, respectively. The higher plant height at compost/soil 1:1 is a demonstration of the presence of available nutrients in the compost which enhanced the growth of plants. The compost had an

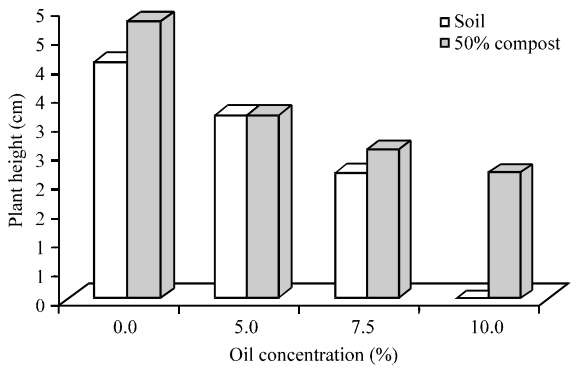

Fig. 4: Plant heights in soil and compost/soil mixtures with oil

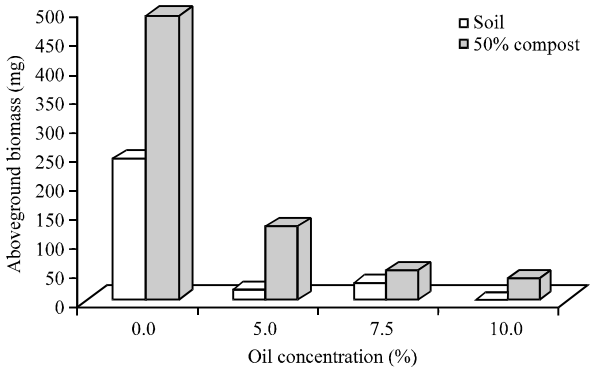

Fig. 5: Aboveground biomass of tomato seeds measured at day 28 for both soil and compost/soil mixtures

organic matter content of 34% as against 9% for the soil. However, there is concern that the use of compost made from biodegradable municipal waste could lead to metal uptake by the plants (Adekunle, 2011). There was no growth at 10% initial oil level, thus no plant height was recorded at this oil level. A decreasing trend for the plant height was observed both for the contaminated soils without treatment and contaminated soils with treatment such that the plant height was decreasing at increasing oil concentration. This shows that oil concentrations affected plant development at varying degrees. It has been reported that oil concentration as low as 0.48% w/w affected plants growth (Kuhn *et al*., 1998).

Biomass yield: Figure 5 represents the biomass yield from the controls and contaminated soils that received treatments. The aboveground biomass was measured at the end of 28 day planting period. In the controls (without oil), the highest biomass yield of 492±159 mg was recorded in the trays containing compost/soil mixture 1:1 compared to 245±19.8 mg in the trays containing only soil. This corresponds to 50% increase in biomass during the period of growth. At 5% initial oil level, the biomass yield was 22 mg compared to 33 mg at 7.5% initial oil levels. This corresponds to 33% increase in biomass yield. Perhaps the presence of higher oil level added to the organic matter content of the soil thereby providing more carbon source for the plants than at 5% oil level. On addition of compost, aboveground biomass yield was enhanced reaching an average of 130±22, 55±9.8 and 40±36 mg for 2.5, 3.75 and 5% diluted oil content, respectively. The dilution effect produced an oil concentration of 5% that allowed plant growth at initial inhibitory level of 10% oil. The higher the oil pollution level, the lower the average biomass yield at compost/soil mixtures.

The aboveground biomass yield recorded in crude oil contaminated soil without treatment suggests that at certain oil concentrations, plants are able to grow. This is supported by the results of Kuhn *et al.* (1998) that Kuwait crude oil allowed plant growth at 0.36% oil concentration and not at 0.48% oil level. However the 100% inhibition to growth observed at 10% initial oil level demonstrates that above a certain oil level, plants are not able to grow depending on the plant' species.

CONCLUSION

Applying compost to soils contaminated with Bonny light crude oil yielded higher biomass compared to soils not treated with compost. The 10% initial oil level is considered as the trigger level at which plants cannot grow. On addition of compost, the least diluted content of 5% oil concentration achieved at 10% initial oil level allowed plant growth. The findings from this study will be useful in identifying the oil concentration that would prevent crop production. The availability of compost to the local farmers makes this a sustainable method of treating contaminated soils. Currently, the method in the Niger Delta for the restoration of oil-contaminated is not acceptable. The study is a contribution to the development of such a guide for treatment of crude oil contaminated soils.

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