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PHYTOREMEDIATION POTENTIAL OF *Vigna unguiculata* IN A CRUDE OIL POLLUTED TROPICAL SOIL OF THE NIGER DELTA

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ABSTRACT

Investigation on the phytoremediation potential of *Vigna unguiculata* in a crude oil polluted tropical soil was carried out at the Botanic Garden, University of Port Harcourt, Rivers State, Nigeria. After one week of post-pollution of the soil with 5% crude oil, *Vigna unguiculata* was sown on the polluted soil and control as a remedial measure. Composite soil analysis was done initially and at every 8 weeks to determine the physico-chemical parameters of the soil for both the treatment and control plots. Results showed that nitrogen content increased from 11.20 to 33.89 mg/kg and conductivity from 11 to 245us/cm, while total organic carbon content reduced from 0.9 to 0.66%, phosphorus 102.3 to 2.28 mg/kg and total hydrocarbon content (THC) reduced from 675 to 130 mg/kg. There was no statistical difference ($p \geq 0.05$) in the soil pH, zinc and copper contents between and within treatments throughout the study period, indicating that, *Vigna unguiculata* is a good phytoremediation plant that can be used in the remediation of crude oil polluted tropical soil of the Niger Delta.

KEYWORDS: Phytoremediation, crude oil, physico-chemical parameters, soil, *Vigna unguiculata*.

INTRODUCTION

During the past century, industrialization has resulted in an ever-increasing reliance on petrochemicals. This, in turn, has resulted in the contamination of a significant number of sites with petroleum and petroleum-byproducts (Bauman, 1991). Hydrocarbon products affect the soil in many ways because oil that penetrates the soil may persist for years (Baker *et al*., 1993). Crude oil reduces the nutrient content of the soil (Xu and Johnson, 1997) and interferes with water and nutrient supply to plants (Grummer, 1965). It also increases the amount of toxic elements in the soil (Odu,1982).

Phytoremediation which is a form of bioremediation, has emerged as an effective remedial measure in crude oil polluted soils. Various plants together with their associated microorganisms have been found to increase the removal of petroleum hydrocarbon from contaminated soil (Reilly *et al*., 1996; Gunther *et al*., 1997; Qiu *et al*., 1997; Pradham *et al*., 1998; Reynolds and Wolf, 1999). Legumes and grasses have been known for their potential in this regard. Pradham *et al*.(1998) reported that alfalfa, switchgrass and little blustem were each capable of reducing the concentration of total polyaromatic hydrocarbon (PAHs) in soil contaminated at a manufactured gas plant. Reynolds and Wolf (1999) also reported that ryegrass lowered significantly the concentration of total hydrocarbon content in soil contaminated with crude oil.

This study aimed at investigating the phytoremediation potential of *Vigna unguiculata* (a legume) in a crude oil polluted tropical soil. It was expected that results obtained will broaden our knowledge on the use of local plants to enhance habitat rehabilitation of crude oil polluted soil of the Niger Delta in Nigeria.

MATERIALS AND METHODS

The study was conducted at the Botanic Garden, University of PortHarcourt, Rivers state of Nigeria. Topsoil from the garden was collected and thoroughly mixed, 5000g of which was put into each of 30 black cellophane bag. A space of 4cm from the top end of the bag was made to make allowance for the addition of crude oil and water. The bags were perforated at the base and sides to avoid waterlog and to increase aeration of the soil. The bags were arranged in three batches of ten replicates each designated as A, B and C.

Crude oil collected from Nigeria National Petroleum Corporation, Eleme, Rivers state was applied as the pollution treatment. 250ml of crude oil was applied to each bag in batch A and B, and thoroughly mixed with the soil on a concrete slab representing 5% pollution level by weight. Batch C received no pollution treatment.

After one week post-pollution treatment, viable seeds of *Vigna* sp bought from Mile III market, Port Harcourt were planted in Batch A and allowed to germinate. After germination, the seedlings were thinned to 5 seedlings per bag. No planting was done in Batches B and C. That is, Batch B acted as the control (i.e polluted soil but no phytoremediation), while Batch C acted as the double control (no pollution and no phytoremediation treatments).

Composite soil samples were collected during each sampling for soil physico-chemical analyses. Soil sampling started one week after soil contamination. This

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period was taken as week 0. Then soil samples were collected after every 8 weeks for analyses.

Soil pH and conductivity were analyzed using Jennway 3015 pH Meter and conductivity meter (Jennway 4010) respectively. Total organic carbon, phosphorus and Nitrogen were determined by the Oxidation, Ascorbic acid and Kjedahl methods respectively (Stewart *et al*.,1974). Total hydrocarbon content was measured at 430nm using DR/3000 HACH Spectrophometre. Zinc and copper were first digested for 15 minutes in electro thermal heater before analysis using Buck Scientific Atomic Absorption Spectrophometer.

All data collected were subjected to two-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Crude oil significantly reduced the nutrient content, soil conductivity and heavy metals but increased the total organic carbon and total hydrocarbon content of the soil. There was no significant difference in the soil pH ($P \geq 0.05$).

Growth of *Vigna unguiculata* in the polluted soil improved the nitrogen content of the soil with time (Fig. 1). At the 24th week, the nitrogen content of the phytoremediated plot was significantly higher than the double control (C). Phosphorus was found to decreased considerably with time in phytoremediated plot as compared to the control (Fig .2). The reason for the improvement in the nitrogen content in the treated plot might be that since *Vigna unguiculata* is a legume, it is able to fixed nitrogen in the soil. Thus, they did not compete with microorganisms for limited supplies of available nitrogen at oil contaminated site, rather they increased the soil nitrogen (Gudin and Syratt, 1975). *Vigna unguiculata* (a legume) can not fix phosphorus as they do for nitrogen, hence they made use of the available phosphate for their growth and metabolic activities, thus depleting the available phosphate leading to a decrease in the phosphate content in the phytoremediation soil. .

Figure 3 shows a significant difference in the total organic carbon (TOC) between treatments and control ($P \leq 0.05$). The same was observed in the total hydrocarbon content (Fig. 4), indicating a "rhizosphere effect" in which the plant (*Vigna* sp) provides root exudates of carbon, energy, nutrient, enzymes and sometimes oxygen to microbial population in the rhizosphere (Campbell, 1985, Cunningham *et al*., 1996; Vance, 1996), thus facilitating the biodegradation process. Increased microbial population implies increased energy (carbon) demand since the oil degrading microorganisms used the carbon as their energy source hence reduction in the carbon content in polluted soil (A) as compared to the double control (C)

As shown in Fig.5, phytoremediation using *Vigna unguiculata* accelerated the conductivity of the soil when compared to the non-remediation plot (B), indicating that *Vigna unguiculata* is capable of increasing the conductivity of oil polluted soil, resulting in an increase in free ion content of the soil. There was no significant difference in the soil pH within and between treatments throughout the study period (Fig. 6). This range of pH (6-9) provided better conditions for mineralization of hydrocarbon since most bacteria capable of metabolizing hydrocarbon develop best at pH condition close to neutrality (Atlas and Bartha,1992; Manuel *et al.*, 1993).

Figures 7 and 8 show that phytoremediation did not significantly affect the zinc and copper content of the oil polluted soil implying that the oil degrading microorganisms do not have any affinity for the heavy metals.

In conclusion, the reduction in total hydrocarbon content and increase in nutrient content (especially Nitrogen) of the soil in the phytoremediation plots as compared to control and double control is an indication that *Vigna unguiculata* is a good plant that can be used in the phytoremediation of crude oil polluted soil in the Niger Delta part of Nigeria.

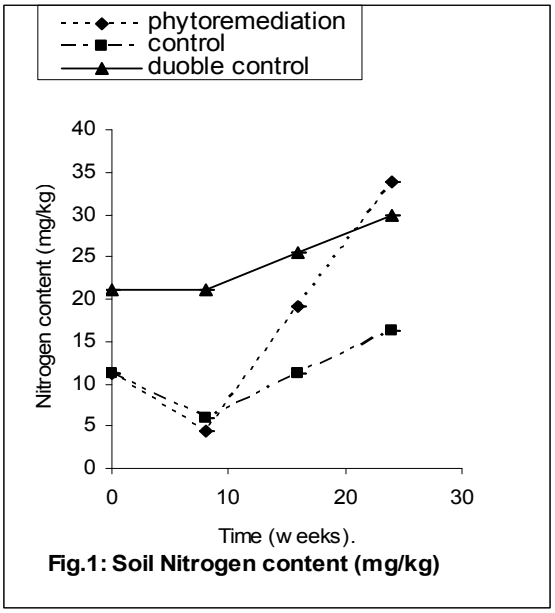

Fig.1: Soil Nitrogen content (mg/kg)

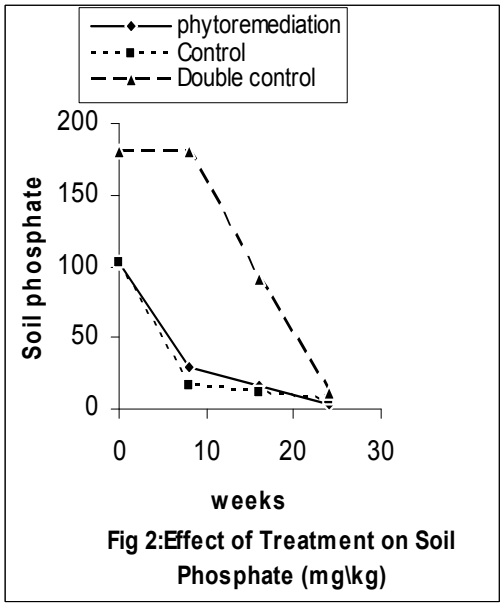

Fig 2:Effect of Treatment on Soil Phosphate (mg\kg)

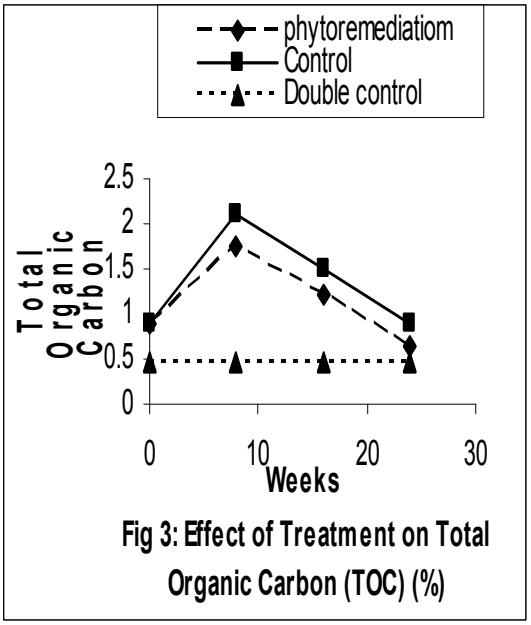

Fig 3: Effect of Treatment on Total Organic Carbon (TOC) (%)

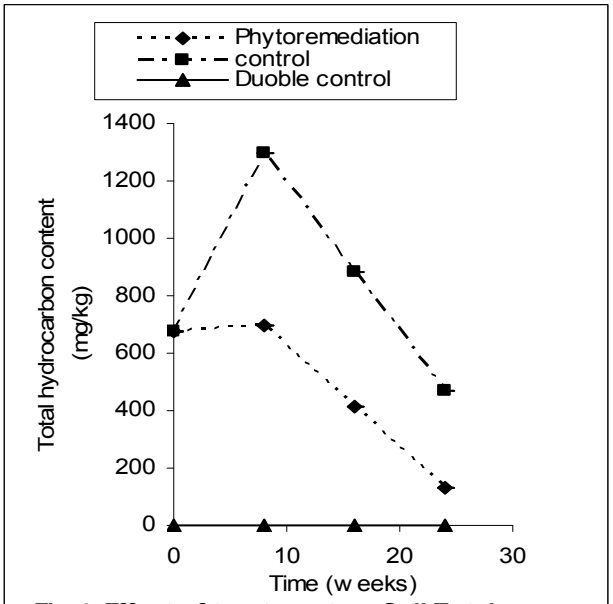

Fig 4: Effect of treatment on Soil Total Hydrocarbon Content (mg/kg)

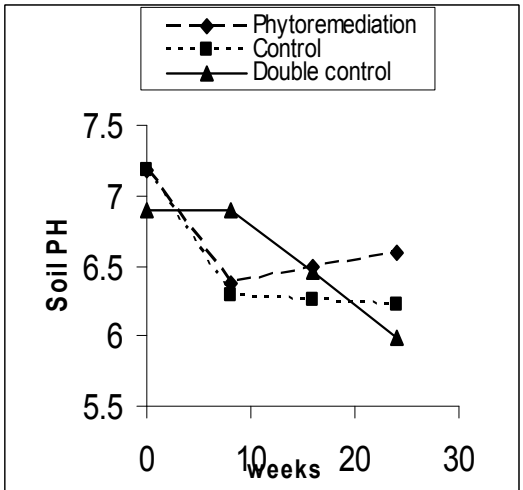

Fig 5: Effect of Treament on Soil pH

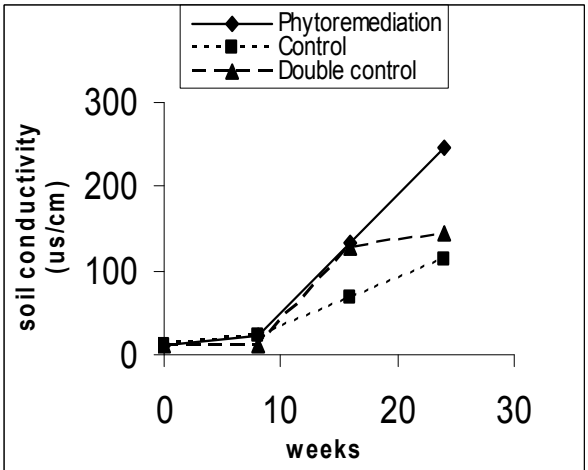

Fig 6: Effect of Treatment on Soil Conductivity (us/cm)

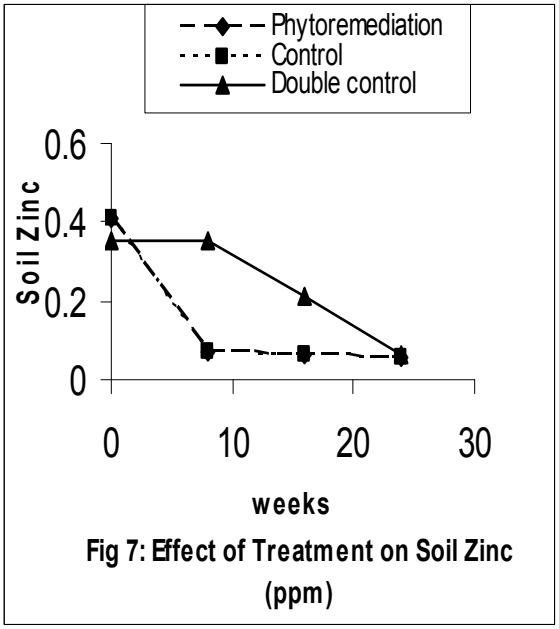

Fig 7: Effect of Treatment on Soil Zinc (ppm)

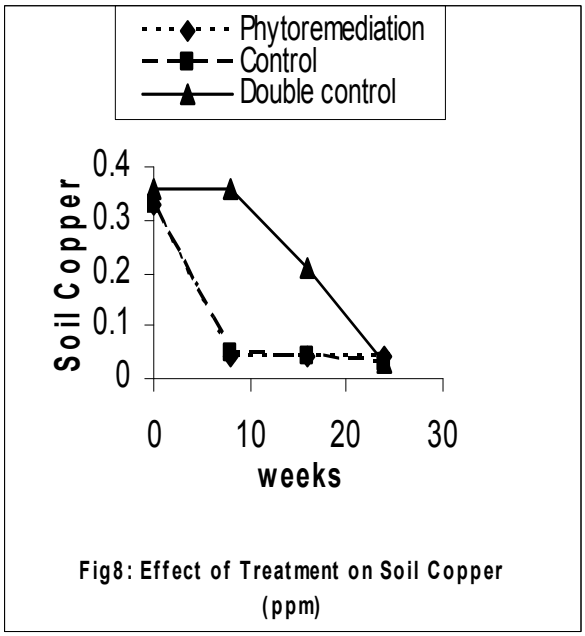

Fig8: Effect of Treatment on Soil Copper (ppm)

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