Effect of Crude Oil Pollution on Growth Parameters, Chlorophyll Content and Bulbils Yield in Air Potato (*Dioscorea bulbifera* L.)

Aniefiok Ndubuisi Osuagwu
Department of Genetics and Biotechnology
University of Calabar
P.M.B 1115, Calabar
Cross River State
Nigeria.

Andrew Ugbede Okigbo
Department of Genetics and Biotechnology
University of Calabar
P.M.B 1115, Calabar
Cross River State
Nigeria.

Imo A. Ekpo
Department of Genetics and Biotechnology
University of Calabar
P.M.B 1115
Calabar
Cross River State
Nigeria.

Peter Nkachukwu Chukwurah
Department of Genetics and Biotechnology
University of Calabar
P.M.B 1115, Calabar
Cross River State
Nigeria.

Reagan Bessong Agbor
Department of Genetics and Biotechnology
University of Calabar
Nigeria.

Abstract

Discovery and utilization of plants with high adaptation to crude oil pollution is currently deemed a safer and cost effective panacea to food security and environmental challenges arising from contamination due to oil spillage in oil producing economies. Against this backdrop, air potato (Dioscorea bulbifera L.) was screened in this study for its tolerance to various levels [5ml/kg, 10ml/kg, 20ml/kg, 50ml/kg] of soil crude oil pollution in a controlled pot experiment, with 0ml/kg serving as control. Results of the study showed that the control plants had significantly better ($p<0.05$) growth and bulbils yield parameters, and higher leaf chlorophyll content than the treated plants. Significantly better growth and yield characters were generally observed with plants grown in soil contaminated with lesser concentrations of crude oil indicating that the adverse effects of the pollution was dose-dependent. The results obtained in this study indicate that although crude oil pollution affected Dioscorea bulbifera negatively, the plant appreciably tolerated the pollution at the levels investigated.

Keywords: Crude oil Pollution *Dioscorea bulbifera* Chlorophyll content

1. Introduction

The myriad of oil exploration and exploitation activities in economies that produce and consume oil products brings about crude oil pollution as a natural consequence. This pollution, according to Agbogidi (2005), is due mainly to accidental discharge human error, sabotage, transportation and other natural causes. In Nigeria, there is a significant spillage of oil into the environment from a number of sources including damaged oil tankers, storage vehicles, leakages of oil pipelines, oil tankers overflow (NAS, 1975; Nicolloti and Eglis, 1998) due to increase in crude oil exploration, exploitation, storage and transportation . This is because oil is the life wire of the Nigerian economy (Adegeye *et al*. 1993) and accounts for over 90% of the national income (Nwilo, 1998). Significant among the damages done to the environment by crude oil spills is pollution of soil which renders it less useful for agricultural activities and affects soil dependent organisms adversely (Lundstedt, 2003). Pollution of agricultural soil has in turn significantly affected the growth performance of plants. Agbogidi (2011) reported that contamination of soil with crude oil significantly reduced biomass accumulation in *Jatropha curcas* when compared to seedlings grown in uncontaminated subplots. He also observed a negative interaction between soil crude oil level and weight gain in the plants. In an earlier study, Agbogidi (2010) reported that spent engine oil affected percentage germination, days to germination and rate of germination in six cultivars of cowpea.

In maize, Okonokhua *et al.* (2007) observed that plant height, root number, root length and grain yield were adversely affected by soil crude oil contamination. Kekere *et al.* (2011) reported that crude oil pollution negatively affected leaf number, total leaf area, plant height, stem girth, total biomass as well as crop yield in *Vigna unguiculata*. They further reported a reduced leaf chlorophyll content, nutritional composition and elevated level of heavy metal uptake in the fruits. Ojimba and Iyagba (2012) observed that the outputs of horticultural crops were significantly reduced in crude oil-polluted farms than in non-polluted farms. They concluded that crude oil pollution had detrimental and negative effect on horticultural crops output, farm income and area of farmland cropped. Njoku *et al.* (2008) reported that addition of cow dung generally improved growth, dry weight, chlorophyll content, leaf area and pod production in *Glycine max* grown in soil contaminated with various concentrations of crude oil.

It has been reported that crude oil in soil makes it unsatisfactory for plant growth (Baek *et al.* 2005). This is due to insufficient aeration of the soil because of displacement of air from spaces between the soil particles by crude oil. Udo and Fayemi (1975) discovered that plants growing in an oil-polluted environment are generally retarded with chlorosis of leaves, coupled with dehydration of the plant. Generally, crude oil contamination causes reduction of plant growth as it interferes in the uptake of nutrients by plants. It also causes competition for the little nutrient available in the polluted soils between plants and soil microbes and ultimately suppresses the growth of plants in such soil.

Considering the detrimental effects of crude oil pollution on plants and its attendant implications for food security and environmental integrity in oil rich regions, it has become necessary to screen for plants with strong tolerance to soil crude oil contamination. Such plants, if discovered may be considered for possible phytoremediation practice in the oil producing areas of the Niger Delta and if certified safe for consumption, will mitigate the food security crises especially for the oil rich region. *Dioscorea bulbifera* L. (air potato) is an underutilized and aggressively growing crop known for its very high tolerance to a variety of soil, weather and habitat conditions ranging from waste places, hill tops, swampy areas, as well as areas largely populated with shrubs (Morisawa, 1999). Cobley (1962) described the medicinal benefits of the plant to include analgesic, diuretic, aphrodisiac and for the treatment of conjunctivitis, hernia, goiter, inflammation, dysentery and food poisoning. There is a general paucity of literature on *Dioscorea bulbifera* L. (air potato) and information on its tolerance to soil crude oil pollution is lacking. Consequent upon this, and in view of the plant's ability to grow and establish in various soil types, it seems a right candidate to be screened in the search for plants tolerant to crude oil pollution, hence the objective of this study.

2. Materials and Methods

2.1 Procurement of Plant Material and Crude Oil

Bulbils of *Dioscorea bulbifera* L. were obtained from Awo-Akpali and Ikom in Ankpa and Ikom Local Government Areas of Kogi and Cross River States of Nigeria respectively. Crude oil was procured from Nigerian AGIP Oil Company (NAOC) in Delta State of Nigeria.

2.2. Experimental Site

This study was carried out in the Biological Sciences garden, Faculty of Science, University of Calabar, Nigeria.

2.3. Methodology

Light loamy soil samples pre-analyzed for physicochemical properties were taken in perforated polythene bags and subjected to four (4) different levels of crude oil pollution – 5ml/kg, 10ml/kg, 20ml/kg and 50ml/kg, with 0ml/kg serving as a control. The soil samples mixed with crude oil were allowed to stay for two (2) weeks to allow proper absorption of the crude oil, after which the physicochemical properties were taken again. Twenty (20) bulbils of *Dioscorea bulbifera* L. were subsequently planted for each of the four crude oil treatment groups and the control. Watering and staking were done when necessary and the plants were allowed to grow freely in a completely randomized design (CRD). Data were taken on some anatomical growth parameters, leaf chlorophyll content and bulbils yield parameters. Data obtained were analyzed using the analysis of variance (ANOVA) and significantly different means were separated using the least significant difference (LSD) analysis.

3. Results

The results of the growth parameters of *Dioscorea bulbifera* L. grown in soil polluted with different concentrations of crude oil compared with control plants are presented in Table 1. Days to sprouting was significantly ($p<0.05$) delayed in the plants grown in crude oil polluted soil (14.95 – 22.40 days) than in the control plants (12.35 days), and was dependent on concentration. There was significant reduction, as the crude oil intensity increased from 5ml/kg to 50ml/kg, in the number of leaves (17.30 – 12.40), plant height (7.99 – 6.05m) and leaf length (10.70 – 6.85cm) in plants grown in crude oil polluted soil than among the control plants (20.00, 9.01m and 11.35cm respectively). Compared with the control plants, leaf area was significantly reduced ($P<0.05$) in the plants grown in crude oil polluted soil while days to heading were significantly increased.

Table 2 shows the results of the leaf chlorophyll content and bulbils yield parameters of *Dioscorea bulbifera* L. (air potato) grown on soil polluted with different concentrations of crude oil compared with control plants. Mean number of bulbils per plant was highest among the control plants (1.85), but significantly decreased as the intensity of crude oil pollution increased from 5ml/kg to 50ml/kg (1.30 – 0.45). Mean weight of bulbils per plant was significantly reduced in the plants grown on crude oil polluted soil and was dose dependent (82.10 – 51.62g), while control plants had a mean bulbils weight of 112.50g. The mean leaf chlorophyll content of the plants grown in crude oil polluted soil was 5.10 and was not significantly different ($p>0.05$) from the mean leaf chlorophyll content of plants grown in 50ml/kg concentration of crude oil. However, plants grown in soil polluted with 5ml/kg – 20ml/kg of crude oil had significantly reduced mean leaf chlorophyll content (4.52 – 3.00) which responded to intensity of pollution.

Table 3 showed the baseline physicochemical properties of soil before and after crude oil pollution. Generally, crude oil contamination significantly reduced the amount of available phosphorus from 37.7 to 2.03 mg/kg, dropped conductivity from 61.90 to 34.59 and increased total hydrocarbon content from 257.20 to 3674 mg/kg. The amount of total nitrogen in the soil sample was minute (0.11%) but was further decreased to 0.07% owing to crude oil contamination.

4. Discussion

The results of this study indicate that crude oil pollution caused delayed sprouting in the air potato bulbils and this was more pronounced at higher levels of soil pollution. Similar findings were reported by Vwioko and Fashemi (2005) and Udo and Fayemi (1975) on dose-dependent adverse effects of crude oil pollution on germination of *Ricinus communis* and maize respectively. This effect may be attributed to disruption in water and nutrient uptake owing to the effects of oil in soil, and the depletion of soil nitrogen and phosphorus content (Baran *et al.*, 2002). Toxic compounds of petroleum hydrocarbon could also have caused inhibition of the plant growth (Bossert and Bartha, 1985).

This finding is further corroborated by the baseline physicochemical studies that confirmed a reduction in soil nitrogen and phosphorus content and an increase in total hydrocarbon content of the crude-oil polluted soil (Table 3). Leaf number was significantly reduced in the air potato plants grown in crude oil polluted soil when compared with the control treatment and the reduction followed increase in crude oil intensity.

This decrease in leaf number can be attributed to a host of factors including blockage of conducting tissues thereby preventing water and nutrients into the plant and limiting their ability to produce more leaves. Okoloko and Berley (1982) also reported that oil pollution impaired membrane integrity, enzymes system especially membrane bound enzymes and affects the metabolic system of the plant. Plant height was significantly reduced in air potato plants subjected to crude oil pollution. Air potato plants generally bear bulbils at the axis where leaves arise from the stem. Greater stem length leads to more bulbils yield. Reduction in stem length directly results in reduction in number of bulbils per plant, hence low yield. This result on plant height agrees with previous findings of Ikhajiagbe and Anoliefo (2011) on the significant reduction of plant growth occasioned by oil pollution. This trend may be explained by the report of Amadi *et al*. (1996) that immediately after an oil spill, there is usually a horizontal migrating of oil into soil horizons. Oily scum on soil surface would impede oxygen and water. It may also cause some toxic elements to be more available to plants thereby causing reduction in plant growth. Therefore the general depression in growth is due to the adverse effect of crude oil.

In the present study, crude oil pollution also caused significant reduction in leaf length and area. This decrease in leaf area of air potato as the intensity of crude oil increased may be attributed to conductance (Smith *et. al*. 1989). Leaf is a site of photosynthetic activities. The reduction in leaf length and area will bring about a consequent reduction in surface area available for photosynthesis hence reducing photosynthetic activities. The reduction in leaf chlorophyll content of the plants grown on crude oil contaminated soil may also have serious implications for photosynthesis.

The yield parameters of air potato were adversely affected by crude oil pollution. There were significantly lower bulbils yield and bulbils number in plants grown in higher levels of polluted soils compared to those in the control. Similar decreases in yield have also been previously reported by Okonokhua *et al*. (2007) and Anoliefo *et al*. (2010) in maize and cowpea sown in oil polluted soils respectively. Ojimba and Iyagba (2012) reported the decreased output of horticultural crops in crude oil polluted farms as compared with the unpolluted farms. This decrease in yield parameters of air potato is an indication that the adverse effects of crude oil pollution on the plant ultimately extend to yield and may have serious economic implications.

5. Conclusions

On the basis of the results obtained from this study, it can be concluded that soil crude oil pollution has an adverse effect on growth, yield and leaf chlorophyll content of air potato (*Dioscorea bulbifera*). However, considering that the plant was able to grow and yield at the concentrations of crude oil pollution studied, it is an indication that it tolerated those levels of pollution and should be investigated further for its bioremediation potential.

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Table 1: Growth Parameters of Dioscorea bulbifera L. Grown On Soil Polluted With Different Concentrations of Crude Oil

Parameters	0ml/kg	5ml/kg	10ml/kg	20ml/kg	50ml/kg
Days to Sprouting	$12.35^{e} \pm 0.1$	$14.95^{d} \pm 0.3$	$16.60^{c} \pm 0.3$	$18.20^{b} \pm 0.2$	$22.40^{a} \pm 0.4$
Number of Leaves	$20.00^{a} \pm 0.5$	$17.30^{b} \pm 0.4$	$15.40^{c} \pm 0.2$	$13.80^{d} \pm 0.4$	$12.40^{e} \pm 0.1$
Leaf Length (cm)	$11.35^{a} \pm 0.1$	$10.70^{b} \pm 0.1$	$9.40^{c} \pm 0.1$	$8.50^{d} \pm 0.1$	$6.85^{e} \pm 0.1$
Leaf Area (cm^2)	$105.40^{a} \pm 0.1$	$68.75^{d} \pm 0.2$	$91.40^{b} \pm 1.0$	$67.10^{e} \pm 0.3$	$73.10^{c} \pm 0.1$
Days to Heading	$68.65^{e} \pm 0.1$	$84.70^{d} \pm 0.1$	$104.90^{b} \pm 0.1$	$127.50^{a} \pm 0.1$	$87.00^{c} \pm 0.1$
Plant Height (m)	$9.01^{a} \pm 0.1$	$7.99^{b} \pm 0.3$	$7.07^{b} \pm 0.1$	$6.51^{c} \pm 0.1$	$6.05^{c} \pm 0.1$

*Means with different superscripts along each column differ significantly from one another

Table 2: Leaf Chlorophyll Content (%) and Bulbils Yield of Dioscorea Bulbifera L. Grown on Soil Polluted With Different Concentrations of Crude Oil

Parameter	0ml/kg	5ml/kg	10ml/kg	20ml/kg	50ml/kg
Chlorophyll content	$5.10^{a} \pm 0.1$	$4.52^{b} \pm 0.3$	$4.00^{b} \pm 0.3$	$3.00^{c} \pm 0.6$	$5.50^{a} \pm 0.1$
Number of Bulbils	$1.85^{a} \pm 0.2$	$1.30^{b} \pm 0.6$	$1.10^{b} \pm 0.8$	$1.00^{b} \pm 0.2$	$0.45^{c} \pm 0.6$
Weight of Bulbils(g)	$112.50^{a} \pm 0.1$	$82.10^{b} \pm 0.4$	$64.75^{c} \pm 0.3$	$52.41^{d} \pm 0.1$	$51.62^{e} \pm 0.6$

**Means with different superscripts along each column differ significantly from one another*

Table 3: Baseline Physicochemical Properties of Soil before and After Crude Oil Pollution

Property	Before Pollution	After Pollution
Moisture (%)	12.52 ± 0.10	10.27 ± 0.06
Sand (%)	84.30 ± 0.76	83.60 ± 0.40
Silt (%)	9.70 ± 0.06	8.80 ± 0.32
Clay (%)	6.00 ± 0.58	7.60 ± 0.17
pH	5.40 ± 0.10	5.70 ± 0.10
Organic Carbon (%)	1.29 ± 0.02	6.92 ± 0.03
Total Nitrogen (%)	0.11 ± 0.01	0.07 ± 0.01
Available Phosphorus (mg/kg)	37.7 ± 0.26	2.03 ± 0.03
Calcium (Cmol/kg)	2.00 ± 0.15	2.40 ± 0.10
Magnesium (Cmol/kg)	1.0 ± 0.10	0.80 ± 0.05
Potassium (Cmol/kg)	0.45 ± 0.01	0.76 ± 0.01
Sodium (Cmol/kg)	0.11 ± 0.01	0.13 ± 0.01
Aluminiun ion (Cmol/kg)	0.95 ± 0.03	1.50 ± 0.06
Hydrogen ion (Cmol/kg)	1.0 ± 0.06	1.80 ± 0.06
ECEC (Cmol/kg)	3.56 ± 0.05	4.09 ± 0.25
BS (%)	45.22 ± 0.75	19.32 ± 1.30
Electrical Conductivity	61.90 ± 0.86	34.59 ± 0.55
Total Hydrocarbon Content (mg/kg)	257.20	3674
Texture	Sandy loam	Sandy loam