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Effect of Crude Oil Concentrations on the Vascular Bundle Size of Two Maize Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. Authors GCA and DOA designed the study and wrote the protocol. Authors NEA and EOO managed the analyses of the study, performed the statistical analysis. Authors SI, OEU and EOO managed the literature searches and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The reliance of humanity on fossil fuels particularly petroleum hydrocarbons has been on the increase and had led to increased pollution of agricultural lands. This study was aimed at investigating the effect of crude oil concentrations on the vascular bundle sizes of two *Zea mays* varieties – Oba Super Zaria (OSZM) and SMZ 37 Kaduna commonly cultivated in the South-eastern Nigeria. The study was conducted in the green house in the Department of Biological Sciences, Faculty of Natural Sciences, Kogi State University, Ayingba, Kogi State. The experiment was setup as a 2 × 4 factorial laid out in a Completely Randomized Design replicated three times with four treatment concentrations (0-control, 15, 30 and 45 ml) of petroleum crude and two maize varieties. Highly significant effects ($P < 0.001$) of the concentrations as well as the varieties were observed on the vascular bundles. The results showed a significant ($P < 0.05$) decrease in vascular bundle sizes with increasing concentration, with plants exposed to 45ml crude oil concentration having the smallest vascular bundle sizes. The vascular bundle sizes of Oba super Zaria decreased significantly ($p < 0.05$) with increasing concentrations of crude oil, while significant

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differences were also observed with the increasing concentrations in SMZ 37 Kaduna as compared to the control. Based on the results obtained from this investigation, OSZM appeared to be more susceptible to soils affected with crude oil.

Keywords: Crude; oil; pollution; soil; vascular bundle; Zea mays.

1. INTRODUCTION

Maize is ranked as the third most essential cereal crop following wheat and rice in the world production of cereal crops [1]. Maize is one of the main staple consumed in Nigeria, as it makes available an inexpensive nutritious food that is of great assistance in sustaining the rapidly increasing population. It also serves as raw material in many industrial processes and in the feeding of livestock [2]. Maize is grown in most agro ecological areas especially in the Niger Delta region where oil industrial activities are predominant [3]. The growth and yield of crops are adversely affected by crude oil pollution, and this has been reported by many workers to include poor and stunted growth, low production and sometimes outright death of crops [4,5,3].

The reliance of humanity on fossil fuels particularly petroleum hydrocarbons had been on the increase. This had led to the increased pollution of agricultural lands, as a result of spillage of crude oil during the process of extraction and processing [6]. In Nigeria, reports have it that from 1976 to 1998, a sum of about 5,724 incidences of oil spills which introduced crude oil to both the terrestrial and aquatic ecosystems to the tune of 2,571,113.90 barrels [7]. Since then, crude oil contamination of farmlands has become common experience in the country, and many of these farmlands have been abandoned in the aftermath of pollution.

The presence of crude oil in the soil renders it inadequate for plant growth, because of the reduced level of available plant nutrients as well as the rising toxic levels of certain micro elements [8]. The susceptibility of plants to crude contamination is high, and plants may end up dying in a matter of few weeks or months. Some plant species are able to grow in hydrocarbon polluted soils and bring about their degradation via the rhizosphere part of their roots. This is because the rhizosphere supports the growth of many microorganisms which increases biomass and microbial activity, thereby accelerating degradation process [9,10].

The essential elements of vascular systems are the xylem vessels, concerned with the transport of water and dissolved salts, and the phloem, which translocates synthesized but soluble materials around the plant to places of active growth or regions of use or storage [11]. Xylem and phloem are normally associated and together form the vascular bundle which is often enclosed in a sheath of fibres. In addition, contains an outer sheath of parenchyma cells (the bundle sheaths) in some instances. Vascular bundles make up the 'plumbing system' of primary tissues, and organs without secondary growth in thickness [11]. This study was aimed at investigating the effect of crude oil concentrations on the vascular bundle sizes of two *Zea mays* varieties – Oba Super Zaria (OSZM) and SMZ 37 Kaduna commonly cultivated in the South-eastern Nigeria.

2. MATERIALS AND METHODS

The soil used in this study was obtained from the top soil collected from a farm land. The soil was treated by sieving and autoclaving at 82ºC for 30 minutes to remove roots that may serve as an alternative host to pathogens that may affect the growth of the plant. Two maize varieties (Oba Super Zaria maize and SMZ 37 Kaduna) were used in this study. Unrefined crude oil was obtained from the Nigeria National Petroleum Corporation, (NNPC). The crude oil was mixed with water to vary the concentration as 15, 30, and 45 ml of the crude oil were mixed up into 500 ml of distilled water.

Five hundred and fifty grams of treated top soil was weighed and put into 24 pots and each pot was planted with three seeds of maize. The planting pots were perforated at the bottom and sides to allow for aeration and drainage of excess water. After germination, the soil in the pots were all polluted with crude oil at the different concentrations (15, 30 and 45 ml), except the control, at two weeks after germination. The experiment was observed for two week with continuous watering. The experiment was setup as a 2 × 4 factorial laid out in a Completely Randomized Design replicated three times. The experimental study was conducted in a green house in the Department of Biological Sciences, Faculty of Natural Sciences, Kogi State University, Ayingba, Kogi State.

The stems were harvested and cross-sections were made using a Reichert sledge microtome. The cross-sections were stained, using the counter staining procedures (Jane 1962), as modified by Ajuziogu et al. [12]. The counter staining procedures stained the lignified tissues of the vascular bundles red, and contrasted them from the unlignified tissues of the grand meristem. Fifteen measurements of vascular bundle diameter were made for each of the various treatment samples and the control at × 100 magnifications using a calibrated microscope.

Data collected were subjected to a two-way analysis of variance via a univariate analysis using IBM statistical package for social sciences (SPSS) version 20. Significant means were separated using least significant difference test generated from GenStat Discovery Edition 4 statistical package.

3. RESULTS

The analysis of variance on the effect of crude oil concentrations and the varietal effect on the vascular bundle sizes were highly significant ($P < 0.001$) across the effect of the varieties, concentration and the combined effect of maize variety interaction with crude oil concentration (Table 1).

The mean differences of the vascular bundle diameter across the varieties as present on Fig. 1 shows that Oba Super Zaria Maize (OSZM) had significantly ($P < 0.05$) wider vessels as compared to SMZ 37 Kaduna. As recorded in Fig. 2, there was a crude oil dose dependent effect on the vascular bundle. As compared to the control which had an average vascular bundle of 0.72 ± 0.08mm, a significant ($P < 0.05$) decrease in vascular bundle with increasing concentration was observed with 45 ml concentration having the smallest vessels (Fig. 2).

At 0 ml of crude oil, Oba Super Zaria maize, (OSZM) had a mean diameter of 0.91 ± 0.00mm which was significantly higher ($p < 0.05$) than every other treatment combinations. This was followed by the vascular bundle of the same variety exposed to 15 ml of crude oil with an average diameter of 0.61 ± 0.01mm which was also significantly wider as compared to higher concentrations (Table 2).

The smallest vascular bundle of 0.49 ± 0.03mm was observed from SMZ 37 Kaduna variety exposed to 45 ml concentration of crude oil. This was however not significantly different from the vascular bundle observed from OSZM variety treated with the same concentration (45ml) and SMZ 37 Kaduna variety exposed to 30ml (Table 2).

4. DISCUSSION

The study showed that an increase in crude oil concentration in the soil decrease the diameter of the vascular bundle in maize. This might possibly be attributed to the differences in polarity between water and crude oil. Water is a high polar solvent while hydrocarbon oil (crude oil) is a non polar solvent, therefore a mixture of water

Table 1. Analysis of Variance (ANOVA) showing the effect of crude oil concentration on two varieties of maize

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F
Variety	0.09	1	0.09	139.67***
Concentration	0.18	3	0.06	93.06***
Variety × Concentration	0.13	3	0.04	67.69***
Error	0.01	16	0.001	
Total	0.40	23		

****- Significant at P < 0.001*

Table 2. Interactive effect of crude oil concentration on the vascular bundle size (mm) of two maize varieties

Concentration	Super Zaria Maize	SMZ 37 Kaduna
0 ml	0.91 ± 0.00^{a}	0.54 ± 0.00^{cd}
15 ml	0.61 ± 0.01^{b}	0.54 ± 0.00^{cd}
30 ml	0.55 ± 0.01^{c}	0.52 ± 0.01^{cde}
45 ml	0.50 ± 0.02^{ce}	0.49 ± 0.03^{e}

**Means with different alphabets on the table are significantly different using Least Significant Difference (LSD) at P < 0.05*

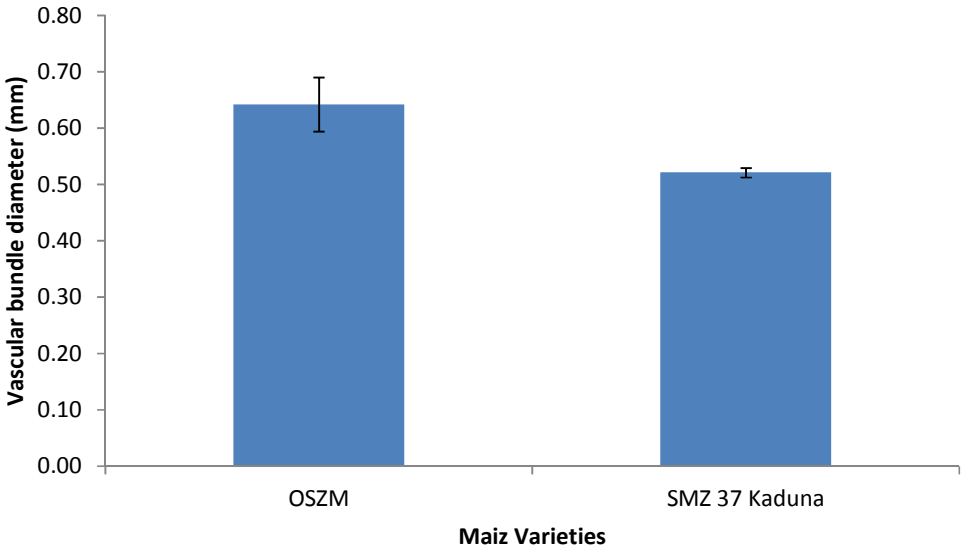

Fig. 1. Mean vascular bundle size of two maize varieties exposed to varied concentration of crude oil

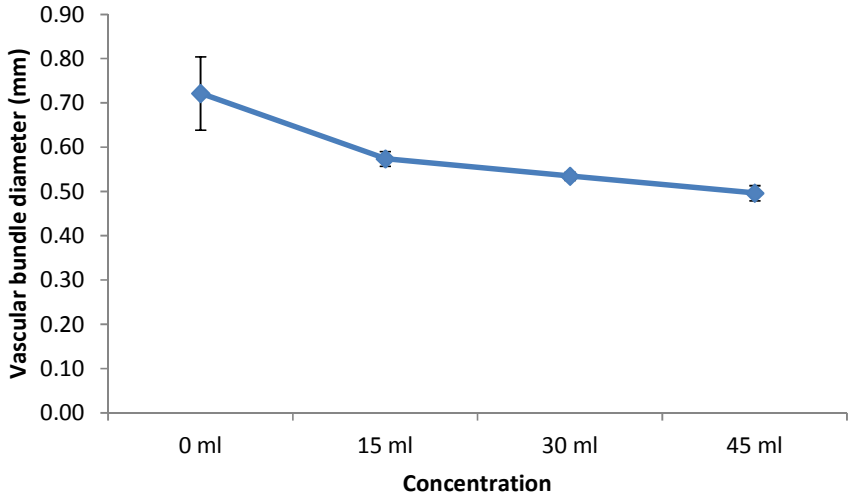

Fig. 2. Mean crude oil concentration effect on the vascular bundle of two maize variety

and hydrocarbon oil will result in formation of two layers, with the hydrocarbon oil layer above and the water below. However, pollution of soil with this mixture of water and hydrocarbon oil would possibly result in the masking or shielding of water molecules and other minerals in the soil by the hydrocarbon oil. As a result of this, there would be no or less uptake of water and other nutrient contained in the soil by plant. Thus in turn would lead to shrinking of the vascular bundles and retardation of plants growth within polluted environment due to impose draught by hydrocarbon oil. Increasing the concentration of crude oil led to a proportional increase in the rate of shrinking of the vascular bundles and hence, reduction in the size of the plant. This reduction of vascular bundle will also lead to slow growth and low yield of grains. These negative effects of

crude oil pollution on crops had been earlier highlighted by Odu [13], Bello et al. [14], Ekundayo et al. [15] and Dung et al. [16]. Therefore, this study supported the findings of the above named authors and confirmed that the results were similar from the point of view of output reduction on crude oil pollution. Similarly Ubochi et al. [17] had reported decrease in nutrients uptake by plants as a result of the oil content in coconut oil effluent.

In view of the dose-dependent decrease in vascular bundle of maize, Anoliefo and Edegbai [18] reported that low level of oil in pollution could be easily be degraded by natural rehabilitation in soils, increase organic matter in soil and improve the fertility, physical and chemical properties of the soil. The differences in the size of vascular bundles of maize varieties in response to crude oil levels corroborates the reports of Baker [19] and Naegele [20] that the effect of crude oil on plants is dependent on the variety amongst other factors. The differences in plants reaction to pollution are due to an innate genetic response of the plant system as modified by environmental influences [19,20].

5. CONCLUSION

Based on the results obtained from this investigation, OSZM appeared to be susceptible to soils affected with crude oil than the SMZ 37 Kaduna variety.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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