Heavy Metal Contents of Maize (Zea mays L.) Grown in Soil Contaminated with Crude Oil

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Abstract: This study investigated the effects of soil contaminated with crude oil on the heavy metal contents of maize. The study was conducted in Asaba and Ozoro locations of Delta State. Open-pollinated AMATZBR maize variety was used. The experiment was laid out in a split-plot design replicated four times. Five crude oil concentrations (0, 5.2, 10.4, 20.8 and 41.6 mL) applied five weeks after planting (5 WAP) constituted treatments. The study locations formed the main plots and the oil levels, the sub-plots. Maize grain was harvested at 14 WAP, shelled and analysed for heavy metal contents. Soil physical properties were also analysed from composite soil samples. The results showed that oil treatment had no significant (p>0.05) effects on soil physical properties. Significant (p<0.05) differences were, however, observed in the heavy metal contents (including iron, zinc, chromium and manganese) of crude oil contaminated soils and the maize seeds harvested there when compared with those harvested from the uncontaminated sub-plots. The present study has demonstrated that crude oil contamination of soil can lead to a gradual heavy metal build-up which, when absorbed are capable of making the maize cobs and leaves potentially toxic and harmful to man and livestock if consumed as food.

Key words: Crude oil, soil contamination, heavy metal contents, maize

INTRODUCTION

Nigeria is a major producer and exporter of crude petroleum oil as well as an important agricultural nation in the West African sub-region (Agbogidi and Nweke, 2005a; Agbogidi et al., 2005a). The continuous exploration, production, processing of crude oil and its transportation exposes the environment to constant threat of oil pollution (Agbogidi et al., 2005a). Oil pollution, whether acute or chronic, has deleterious effects on agricultural lands and hence significant effects on plant growth (Agbogidi et al., 2005b, 2006, 2007; Atuanya 1987 and Benka-Coker and Ekundayo, 1995) reported that oil pollution tends to change the physical, biological and chemical properties of soil thus, affecting plant growth and subsequent yields. Oil pollution has been reported to create some conditions in soils, which make some essential mineral nutrients unavailable to plants and make some non-essential ones either readily available or cause them to rise to a toxic level (Udo and Oputa, 1984; Atuanya, 1987; Ekundayo and Obudeke, 1997; Siddiqui and Adams, 2002). Heavy metal pollution occurs when heavy metals are introduced into the environment either naturally or by man’s activities resulting in an unfavourable change in such a way that the safety and welfare of any living organism is endangered.

Although some research works have been carried out on oil pollution on crop plants: soyabean (Udo and Oputa, 1984), melon (Anolfeho, 1991), hot pepper and tomatoes (Anolfeho and Vwiofo, 1995), fluted pumpkin (Asuquo et al., 2002), okra (Agbogidi and Nweke, 2005b; Agbogidi et al., 2007), there is paucity of information on the effects of crude oil contaminated soil on the heavy metal content of maize in Delta State. Maize (Zea mays) is an important staple crop in Nigeria (Obi, 1991). It is one of the staple foods consumed by the teeming population of Nigeria in large amount. Maize ranks third in the world production of cereal following wheat and rice (FAO, 2002). It is used as feed for livestock and a principal raw material for many industrial products (FAO, 2002; Agbogidi et al., 2007). A study on the effects of crude oil on maize in Delta State is necessary as it will provide information on the efficient management of crude oil contaminated soils in maize growing areas of the State. The present study was designed to evaluate the heavy metal contents of maize grown in crude oil contaminated soil with a view to determining the risk, if any, to the consumers of maize grown in crude oil impacted soils.

MATERIALS AND METHODS

Study locations: The study was carried out in Asaba and Ozoro locations in Delta State. Asaba (latitude: 06°14'N, longitude: 06°49' E, temperature: 28±6°C, rainfall 1505-1849 mm, relative humidity: 69-80% and monthly

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sunshine: 48 bars), is located in the rainfall agro-
ecological environment (Asaba Meteorological Station,
2003). Ozoro lies between latitude 6° 13'E and longitude:
5°33'N and it is under the rainforest ecological zone of
Delta state. Ozoro experiences double peak periods of
rainfall between June/July and September/October,
respectively. The annual rainfall is 2800 mm while that
of the temperature is 31°C and relative humidity
76-90% (Anonymous, 2003). The experiment took place
between April and September 2003 and 2004 cropping
seasons.

Experimental materials and design: NPK fertilizer (20-10-
10) used for the study was obtained from the Delta State
Agricultural Procurement Agency, (DAPA) Ibusa, Delta
State. It was applied prior to planting based on the
analytical information of the soil nutrient status. The
crude oil used (with specific gravity of 0.8334 g cm⁻³ and
API gravity of 34.2897) was obtained from the
Nigerian National Petroleum Corporation (NNPC), Warri. The maize
(AMATZBR w) was sourced from the International
Institute of Tropical Agriculture (IITA), Ibadan, Oyo
State.

The experimental design was a split-plot arrangement
replicated four times. Location of study formed the main
plots while the crude oil levels were allotted the sub-plots.
A sub-plot (2.8125 m²) contained 24 stands of maize.
Planting was done in 2003 and 2004 cropping seasons in
both locations. Between row spacing was 75 cm and
within row was 25 cm. Five crude oil levels (0, 5.2, 10.4,
20.8 and 41.6 mL) were applied to soil (ring application) at
five Weeks After Planting (WAP). Ears were harvested at
14 WAP and mechanically shelled. The maize seeds were
ground and each of the meals of the maize samples were
dried, weighed and a known amount ashed and then wet
digested using nitric acid. The digests were later analysed
for heavy metals by atomic absorption spectrophotometry
using the standard addition method. Soil analysis was
also carried out to determine soil physical properties. The
analysis was carried out at the Nigerian Institute for Oil
Palm Research (NIFOR) near Benin, Edo State. Concentration of heavy metals including iron, zinc, copper, manganese, lead, chromium, nickel and cadmium was determined after digestion of soil samples with hydrofluoric acid and perchloric acid. The concentrations of the elements were read by means of an atomic
absorption spectrophotometer. Data collected were
subjected to analysis of variance and the significant
means were separated with the Duncan’s multiple range
tests using SAS (1996).

RESULTS

Particle size analysis of Anwai and Ozoro locations
showed that the soils are of sand textural class, with silt-
and clay contents ranging from 0.3 to 3.4 (Table 1).
Treatments had no significant effect (p>0.05) on soil
physical properties. However, visual observation showed
that plots treated with crude oil reduced water infiltration
and percolation in the soil. This resulted in water
accumulating in small pools. Air-drying of the crude oil
oiled soils took relatively longer time. On drying, the
soil gave a cemented waxy appearance which more or less
repelled or resisted water/re-wetting.

There was a build-up of heavy metals in the soils
contaminated with crude oil. Soil contents of Fe, Zn, Cu,
Mn, Pb, Cd, Cr and Ni were significantly (p<0.05) higher
in soils contaminated with crude oil when compared with
the control sub-plots (Table 2). The maize seeds analyses
also showed significantly higher amounts of heavy metals
when compared with those grown in the uncontaminated
soils at the 5% probability level (Table 3).

Table 1: Effect of different crude oil levels on some soil physical properties at Asaba and Ozoro locations

<table>
<thead>
<tr>
<th>Crude oil levels (mL)</th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>Sand (%)</th>
<th>Texture</th>
<th>Bulk density (Mg m⁻³)</th>
<th>Particle density (Mg m⁻³)</th>
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<tr>
<td>Asaba location</td>
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<tr>
<td>0</td>
<td>3.4a</td>
<td>2.1a</td>
<td>94.5a</td>
<td>Sand</td>
<td>1.37a</td>
<td>2.74a</td>
</tr>
<tr>
<td>5.2</td>
<td>3.1a</td>
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<td>96.0a</td>
<td>Sand</td>
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<td>97.6a</td>
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<td>Sand</td>
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<td>2.66a</td>
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Means in the same column with same letter(s) are not significantly different (p>0.05), using DMRT.
Table 2: Heavy metal content (mg kg⁻¹) of soils under different crude oil treatments

<table>
<thead>
<tr>
<th>Crude oil level in soil (mL)</th>
<th>Fe</th>
<th>Zn</th>
<th>Cu</th>
<th>Mn</th>
<th>Pb</th>
<th>Cd</th>
<th>Cr</th>
<th>Ni</th>
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<td>0.49d</td>
<td>0.05c</td>
<td>0.03d</td>
<td>0.03d</td>
<td>0.86c</td>
<td>3.10e</td>
<td>2.28e</td>
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<td>0.84c</td>
<td>0.78c</td>
<td>0.09c</td>
<td>1.58c</td>
<td>0.06d</td>
<td>0.90c</td>
<td>4.62d</td>
<td>4.30d</td>
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<td>0.89c</td>
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<td>0.15ab</td>
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<td>0.15ab</td>
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<td>0.18a</td>
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<td>0.41d</td>
<td>0.05c</td>
<td>0.71d</td>
<td>4.20d</td>
<td>2.46e</td>
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<tr>
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<td>0.95c</td>
<td>0.10c</td>
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<td>0.08c</td>
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<td>14.21a</td>
<td>12.00a</td>
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</table>

Means in the same column with same letter(s) are not significantly different (p<0.05), using DMRT.

Table 3: Heavy metal content (mg kg⁻¹) of maize seeds as affected by different crude oil levels in Asaba and Oturo

<table>
<thead>
<tr>
<th>Crude oil levels (mL)</th>
<th>Fe</th>
<th>Zn</th>
<th>Cu</th>
<th>Mn</th>
<th>Pb</th>
<th>Cr</th>
<th>Ni</th>
<th>Cd</th>
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</table>

Means in the same column with same letter(s) are not significantly different (p<0.05), using DMRT.

**DISCUSSION**

The non significant (p<0.05) effects of crude oil application on soil physical properties in both locations studied may be due to the relatively low C:N content of the crude oil treatment of the soil sample. Low C:N content of treatment materials may not have much influence on soil particle size distribution, bulk density and porosity since such materials are rapidly mineralised to release their nutrient components by soil organisms (Nnaui et al., 2005). However, cultivation of land and soil management practices adopted in the process of crop production may tend to lower the total pore space (Udo and Ogunwale, 1986) compared to that usually associated with a decrease in organic matter content and as a consequent lowering of granulation. Similar results of non significant influence of crude oil on soil texture, bulk density of porosity had been observed by Asuquo et al. (2002).

The observed build-up of heavy metals with increasing level of oil supports the findings of Udo and Opata (1984) and Ekundayo and Obuekwe (1997). These heavy metals present in the oil polluted soils, when absorbed by plants are capable of making the maize cobs and leaves potentially toxic and harmful to man and livestock if ingested or consumed as food (Ogri, 1998).

This finding is in agreement with the report of Benson and Ebong (2005) on vegetables. Similarly, heavy metal accumulation in plants may lead to poor growth resulting in yield reduction. Lead and cadmium for example have been reported by Epstein (1972) to prevent mineral uptake by either synergistic or antagonistic reactions.

Although the amounts of these metals found in the soil samples were below lethal doses than those given by FAO (1976 and 2002), with gradual and steady deposition of such heavy metals in the soils, it may build-up to toxicity level. Charman and Murphy (1992) and Sherertz (1998) noted that because some components of crude oil are highly lipophilic, even small amounts entering the environment accumulate in organisms as a result of gradual and steady build-up. Possible bio-accumulation of the metal in the liver and kidney of man and his animals arouses a significant interest since man has the ability of bio-concentrating small doses of deleterious chemicals in his liver and kidney such that harmless quantities of poisonous chemicals would eventually build-up to dangerous levels. Heavy metals contents from both the contaminated and uncontaminated soils still fall below the critical values (Fe 40 ppm, Zn 43 ppm, Cu 36 ppm, Mn 48 ppm, Pb 140 ppm, Ni 35 ppm, Cr 100 ppm and Cd 39 ppm) recommended by FEPA (2002).
Despite uptake of heavy metals by the maize plants, their low residues in soils were still higher compared to the control sub-plots. Generally, metals tend to accumulate in the clay fraction of the soil because clay-sized particles have a large number of ionic binding sites due to a higher amount of surface area (Epstein, 1972; Garcia et al., 1979). Epstein (1972) further maintained that metals could be tightly bound to organic matter content of the soil, which is gradually released during the process of mineralisation. Singh and Mishra (1987) reported that heavy metals retard seedling growth in rice and corn. Similar finding has been reported by Khan and Frankland (1983) for radish. The increase in the heavy metal contents of maize seeds is attributed to the increase availability of such cations in soil due to the anaerobic reducing environments caused by the oil in the soil. The high content of Mn in the plant tissues gives an indication of Mn toxicity (Badoglio and Stumm, 1994; Cobb et al., 2000) with time. Black (1957) and FMANR (1990) had earlier reported that as little as 4 ppm Mn caused yield depression while Adams and Ellis (1960) observed that gas-saturated soil contained over 60 ppm of exchangeable manganese ions and 120 ppm of exchangeable ferrous ions. The presence of these heavy metals in maize plant could induce yield reductions. Benson and Ebong (2005) reported that the poor growth of crops in higher levels of oil treatment was due primarily to the toxic effects of heavy metals or mineral uptake.

CONCLUSIONS

The study has demonstrated that crude oil contamination can lead to gradual heavy metal build-up in the soil and consequently, a significant increase in the heavy metal contents of maize grown in such soils. The poor soil conditions following oil application may be due to sub-optimal soil aeration and an increased demand of oxygen caused by increased population of oil decomposing microbes attracted to the soil as a result of the contamination.

From this study, it is recommended that Agronomists and Food Scientists need to conduct further research on the effects of growing other food crops in oil-contaminated tropical soils and monitoring the concentration of the oil pollutants, by-products and heavy metals in the plant tissues so that a reliable database can exist on how such heavy metals affect food safety, grain storage and spoilage problems in the rainforest zone of sub-Sahara African countries including Nigeria. Research on the combined application of crude oil, wastes and other organic amendments could also be carried out to determine how such amendments could help in the degradation of heavy metal content of the crude oil.

REFERENCES


