EFFECT OF CRUDE OIL AND SOLUBLE METAL SALT CONTAMINATED SOIL ON *Zea mays* PLANT GROWTH INDICES

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Abstract: Various parameters, such as growth index used to evaluate the productivity of a good agricultural soil were integrated in this study and critically examined under a pollution condition. The indigenous Nsukka soil representing a typical tropical soil was contaminated with calculated quantities of a given Nigerian crude oil (Bonny Light B-111). Growth indices of *Zea mays* planted as wellasnursery transplants was carried out on contaminated soil to observe the effect of the crude oil on the plant.Various plant growth parameters such as: height of plant, length and breadth of leaves were examined. The result of the experiment illustrated that there was a great significant difference ($P<0.05$) in the various growth parameter (Plant height, Length and Breadth of leaves) between *Zea mays* produced after 5 weeks in control soils (A and B) when compared to those grown on contaminated soils (5%, 10%, 15% and 20% (petroleum hydrocarbon) PHC w/w).There was reduction in the plant length, leaf length and breadth of all *Zea mays* plant cultivated on the crude oil contaminated soil. The character of these measured parameters (*Zea mays* grown in contaminated soil) showed that they were half the value of the controls.Between the non contaminated soil (control A) and the soluble metal contaminated soil (control B), there was slight reduction in *Zea mays* grown in soil contaminated with soluble metal salt only. Thus, the results clearly illustrated that crude oil contamination negatively and adversely affect the productivity of the Nsukka soil ipso facto the production of *Zea mays.*

Keywords: *Zea mays, parameter, crude oil, unspiked soil, spiked soil.*

Introduction

Changes in soil properties due to contamination with petroleum-derived substances can lead to waterand oxygen deficits as well as to shortage of available forms of nitrogen and phosphorus (Njoku *et al.,* 2009). The ability of crops to germinate or grow on crude oil polluted soil is dependent on the level of crude oil spillage on soil (Odu, 1972). This means that a high level of crude oil pollution of the soil impairs germination of seedlings. Reweel (1977) stated that at low level of spillage e.g. one percent of oil contamination, germination may be delayed due to lack of moisture and hardening of soil structure. Moreover, at high contamination of soil, there may be no germination. Hence seed rotting will take place due to seeping of crude oil into the seeds through the outer integument.

The interference of oil to soil air and water is another means of inhibiting seed germination. McGill (1976) noted that the toxic effect of crude oil coupled with poor aeration with wettability of the soil due to oil spillage results in poor seed germination.According to Plice (1948), petroleum hydrocarbons (PHCs) ‘sterilize’ the soil and prevent crop yield for varying periods of time. The negative impact of oil exploration activities remain the major cause of depletion of the Niger Delta vegetation cover and the mangrove ecosystem (Odu, 1987). Some plants accumulate heavy metals by transporting the metals and concentrating them into their shoots for harvesting even though it could affect water retention as well as protein content in their biomass production. *Zea mays* happen to be one of such plants (Ezeonu, 2010).

Soil nutrient depletion takes place when the components which contribute to fertility are removed and not maintained. This leads to poor crop yields. When a soil is polluted with crude oil, plant growth becomes adversely affected for some time and after a period the hydrocarbons become decomposed and are converted to soil organic matter which may improve the nutrient content of the soil. However, this could take a long period of time under which the soil may remain unproductive for agricultural purposes. In Nigeria, maize is the most important staple cereal after sorghum and millet with the widest geographical spread in terms of production and utilization among the cereals (Omoloye, 2009). Maize is grown in all parts of the country, though it is grown slightly more in the savannah belt of the country. All parts of the crop can be used for food and non-food products (IITA, 2010).

According to Ezeonu (2013), each of the percentage (5%, 10% and 20% PHC) crude oil contaminated soil indicated that very little quantities of crude oil remained in the soil after 8 weeks of cultivating the polluted soil with *Zea mays* plant. These results revealed that degradation of petroleumhydrocarbon tookplace as a result of the activities of weathering by plant root, the climate, water and micro-organisms. Therefore, *Zay mays* have high resilience in crude oil and metal polluted soil. The quality of a good soil depends on its ability to retain and release all the necessary abiotic components such as soil water, nutrients/chemical and soil air to the root of the plant for successful thriving of the crop (Hill, 1952). It can be concluded that crude oil spillage on farm land has both positive and negative effect on soil. This work is aimed at determining the effect of crude oil contaminated soil on various *Zea mays* growth parameters.

Materials and Methods

Materials

Hand Trowel, Spades, Hoes, Containers, Ohaus weighing balance, polythene planting bags, Thermometers, Measuring tapes.

Test sample

The test sample used in contaminating the soil microcosm was crude oil obtained from the Department of Petroleum Resources (DPR), Port Harcourt. The crude oil is referred to as "Bonny" light (B-III Nigerian). Soluble metal salts from K_2SO_4, $CaCl_2$ and $MgSO_4$ were also used.

Plant material

Viable *Zea mays* seeds were purchased from Ogige market Nsukka, Nigeria and used in this experiment.

***Zea mays* Planting and Monitoring**

Viable maize seeds were obtained from Ogige market Nsukka and identified by the Department of Crop Science, University of Nigeria, Nsukka. The seeds were used for the experiment.The seeds were soaked in distilled water and their viability determined by floatation (seed priming ie good seeds did not float) for 48 hours before sowing. Planting was done within 3 cm depth of two seeds per hole in triplicate per pot and 18 cm distance between planting depths for all the soil samples. Additional seeds were also cultivated on the field around the experimental soil and subsequently used as nurseries. Germination was observed specifically for the growth of the cotyledons above the soil surface for some days. The nurseries were then transplanted into the various contaminated soil samples (5%, 10%, 15%, and 20% w/w [weight of crude oil/weight of soil]) and controls.The maize seeds were planted under field conditions of (32 ± 4^oC), 12 hrs light: dark photo periods.

Plant Analysis

All the analysis on the plant (maize) took place between 5 weeks to 2 months of maize germination/nursery transplant and growth. The leaves height and breadth as well as plant height were measured.

Experimental Design

Forty kilograms (40 kg) of soil were collected beside animal house of the Department of Biochemistry, University of Nigeria, Nsukka. The soil was weighed, air/sun dried and stones and debris were removed manually. The soil was then weighed out into five different soil microcosms of 8kg each. These constituted two controls and three experimental variable samples. A quantity of 32 kg of the soil was spiked by mixing thoroughly with 1litre of 1M solution of the salts (K2SO4, $CaCl_2$ and $MgSO_4$). The spiked soil was divided into 4 groups of 8 kg each, consisting of Control B (spiked control) and the test samples.

The test soil samples were contaminated with crude oil in the concentrations of 5%, 10% and 20 % w/w. Each of the soil samples was divided into 2 equal parts and placed in polythene planting bags kept in the field and 6 viable *Zea mays* planted (planting was done within 3 cm depth of two seeds per hole in triplicate per pot and 18 cm distance between planting depths for all the soil samples) on each after 7 days of soil preparation. Nurseries of the *Zea mays* seeds were also raised and used for transplanting. After 5 weeks, growth parameters namely: leaf height and breadth, were determined daily for 14 days. The daily plant height was also documented. The mean of various plant leaf height and breadth from each group was calculated, the standard deviation obtained and data were analyzed using the SPSS package for windows version 16.0 (SPSS Corporation). Differences between the means were separated using One-way ANOVA, while LSD multiple comparison statistical package was used to make comparison between groups. Differences in means with $p \leq 0.05$ were accepted as significant. Data were presented as Means± Standard Deviations.

Results and Discussion

Plant measurement

The various parameters measured include: height of *Zea mays* plant, leaf lengths and leaf breadth. This was carried out for 2 weeks after 5 weeks of *Zea mays* growth.

Height of Zea mays plant

Fig. 1, illustrated that among the controls, the unspiked soilproduced *Zea mays*with better height than the spiked soils.The mean height of *Zea mays* for the various soil samples are as shown belowin order of decrease: Unspiked soils (control A) > Spiked soils (control B) > 20% PHC soils > 10% PHC soils > 5% PHC soils. Fig. 1 also showed that the height of Zea *mays* for each soil group from day one to day fourteen of measurement gave no significant difference (P>0.05). Fig. 2 showed that the mean height of *Zea mays* between the two controls had no significant difference (P>0.05). But when the control (unspiked and spiked) soil samples and the contaminated test soil samples (5%, 10% and 20% PHC w/w soils) were compared, theheight of *Zea mays* produced at the same period differed significantly (P<0.05) (Fig. 2).

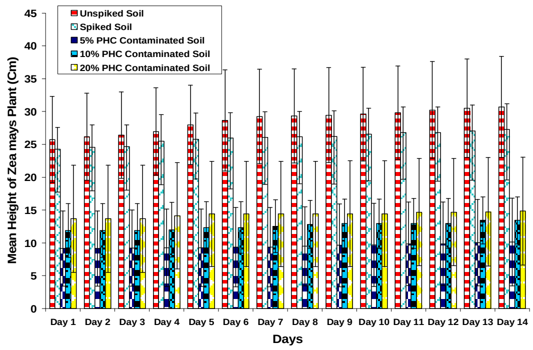

Fig. 1: Daily mean *Zea mays* heights for 14 days after 5 weeks of cultivation

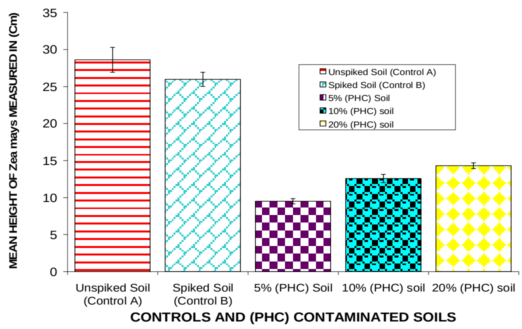

Fig. 2: Total groupedmean height of *Zea mays* for 14 days after 5 weeks of cultivation.

Breadth of leaves

The breadth of *Zea mays* leaves measured for two weeks after their fifth week of growth in the various soil samples showed a mean leaf breadth increase in the following order: 10% PHC soils and 20% PHC soils < 5% PHC soils < spiked soils (control B) < unspiked soils (control A) see Fig. 3.There was a little increase in leaf breadth in *Zea* *mays* cultivated in each soil microcosm which stopped after day 3 in the unspiked soil and day 5 on the spiked soil. Figure 3 illustrated that the increase in breadth of *Zea mays* leaves in each of the individual soil microcosm of the separate groups had values that are not significantly different (P>0.05) from the first day to the fourteenth day.

Thus the grouped mean breadth of Fig. 4 indicates the fact that unspiked soil (control A) when compared with spiked soil (control B) produced on average *Zea mays* leaves whose breadth did not differ (P>0.05) from each other statistically. Again 10% PHC soils and 20% PHC soils had *Zea mays* produced on them whose average breadth of leaves are of the same value each (Table 4) and at the same time all the breadth of leaves of *Zea mays* produced in all the test soil samples (5%, 10% and 20% PHC soils) had no significant difference (P>0.05) from each other in their values as shown in Fig. 4, although 5% PHC soil had *Zea mays*with a little higher leaf breadth than the other two test soils. Between the control soils and the test(contaminated) soil samples, the *Zea mays* leaves cultivated at this period differed significantly (P<0.05) since the control soils had higher *Zea mays* leaf breadth than the crude oil contaminated test soil samples.

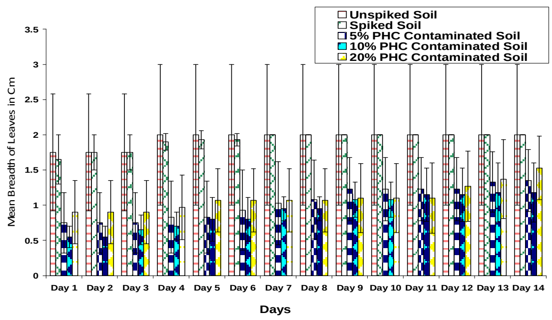

Fig. 3: Daily mean breadth of *Zea mays* leaves for 14 days after 5 weeks of cultivation

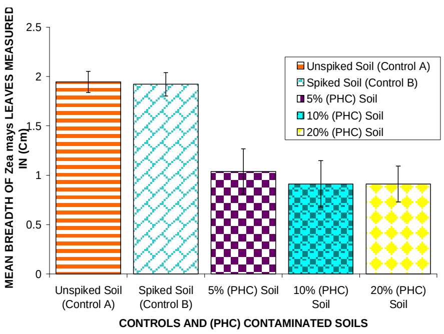

Fig. 4: Total groupedmean breadth of *Zea mays* **leaves for 14 days after 5 weeks of cultivation**

Length of leaves

Fig. 5 illustrates the fact that the *Zea mays* grown on each group of soil (controls A and B as well as 5%, 10% and 20% w/w PHC soils) from the first to the fourteenth day of measurement, experienced a little increase in length of leaves within each group which was statistically not significant (P>0.05). Fig. 6, illustratesthe mean leaf lengths of *Zea mays* grown on the various soil groups. The length of leaves decreased as follows: unspiked soils (control A) > spiked soils (control B) > 20% PHC soil > 5% PHC soil > 10% PHC soil.

The histogram of Fig 6 and statistical analysis indicates that between the unspiked soil (control A) and spiked soil (control B), the length of leaves of the *Zea mays* grown in them differed (P<0.05). The unspiked soil had a higher *Zea mays* leaf length than the spiked soil. Also, between the controls and test soil samples the length of leaves differed significantly (P<0.05) since the controls produced *Zea mays* with longer leaf lengths. Between the contaminated soils, length of leaves of *Zea mays* produced on 20% PHC soils was longer and differed significantly (P<0.05) from those of the 5% PHC soil and 10% PHC soils re, spectively. However, Zea *mays* leaf lengths of 5% PHC soil when compared with those of 10% PHC soil gave no statistically significant difference (P>0.05) even though 5% PHC soil had slightly higher *Zea mays* leaf lengths than those of 10% PHC soil.

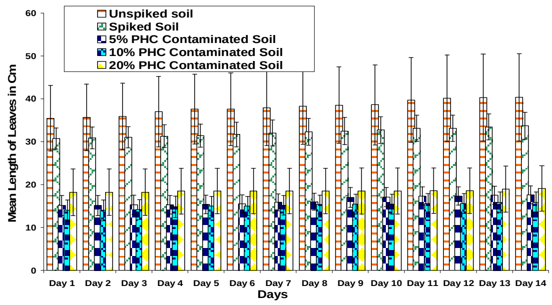

Fig. 5: Daily Mean Length of *Zea mays* leaves for 14 days after 5 weeks of cultivation

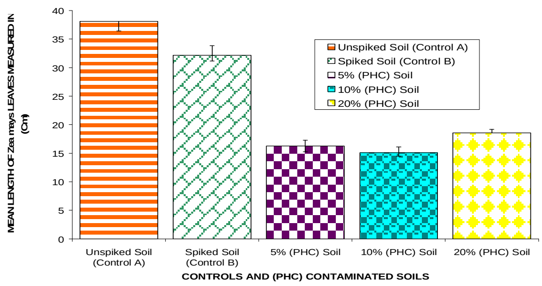

Figure 6: Total grouped mean length of *Zea mays*leaves for 14 days after 5 weeks of cultivation

In this research, *Zea mays* germination was observed specifically for the growth of cotyledons above the soil surface for a period of one week. The two controls (Control A or unspiked soil and Control B or spiked soil) had above 85% germination after 5 days while 5% w/w crude oil contaminated soil had below 9% germination. Moreover, no germination was observed on 10% and 20% w/w crude oil polluted soils, respectively. This observation collaborates with earlier works on the effect of soil pollutants on germination and growth of plants (Dejong, 1980; Udo and Fayemi, 1975). According to Targe (1984) germination of seeds in polluted soil varied with different plant species.

The growth and germination of *Zea mays* was observed to be more sensitive to crude oil than other plants such as red bean (Baek *et al*., 2004). Root development was acutely reduced in soil contaminated with as little as 1% (w/w) crude oil. Indeed, Baek *et al*. (2004) observed that *Zea mays* was entirely unable to germinate in 5% (w/w) oil contaminated soil which is similar but not exactly the case with this experiment where less than 9% germination was observed. Odu (1972) and Rowell (1977) stated that at low level of spillage e.g. one percent (1%) of crude oil contamination, germination may be delayed due to lack of moisture and hardening of soil structure. Moreover, at high contamination of soil, there may be no germination. Hence seed rotting will take place due to seepage of crude oil into seeds through the outer integument.

Thus, another independent research (Ayotamuno and Kogbara, 2007) had similar result with that of this experiment, which collaborated the fact that *Z. mays* has high tolerance level compared to many other crops and could be grown (or continue to grow) on crude oil contaminated soils with contaminant concentration of about 21% by volume of the soil. Thus 21% soil contamination could be identified as the "lethal threshold" for maize crop growing on crude oil contaminated soil with adequate nutrient supplementation and irrigation. Greater percentage level of crude oil contaminated soil (>21%) has experimentally failed to support the growth of *Zea mays.* The growth sensitivity of *Zea mays* to crude oil was also observed by Akaninwor *et al.* (2007) in which Bonny light crude oil simulated contaminated soil permitted germination of guinea corns at 5% w/w as well as allowed for thriving of the germinated plants. At 20% w/w crude oil contamination however, the crude oil was not only able to inhibit germination of guinea corn but also considerably was effective against seedling growth. Again this is similar to the result obtained in this experiment except that transplanted *Zea mays* seedlings grew for some time although the growth was stunted as observed in the course of this research.

Suppression of germination and subsequent growth of plants by crude oil contaminated soil could be as a result of impairment of the biochemical processes such as enzyme synthesis taking place during germination (Akaninwor *et al.,* 2007). Oil contaminated soils generally causes delayed seed emergence (Anoliefo and Vwioko, 1995). This has been suggested to be as a result of poor wettability and aeration of the soil (Isirimah *et al*., 1989) and loss of seed viability (Rowell, 1977).

The mean plant height (height obtained as shown in Figs. 1 and 2) showed that between the various group treatments there was a mean significant difference in height (P<0.05). The highest value was obtained in plants cultivated in Control A (Unspiked) natural Nsukka agricultural soil and the least value was obtained in plants cultivated in the least crude oil contaminated soil (5% w/w). The two controls showed luxuriant growth even though the spiked soil produced plants of lesser height than those of the unspiked. The reason for this could be due to metal accumulation on the plant shoots of *Zea mays* in the spiked soil. The result is collaborated by observations made by Peciulyte *et al*. (2006), in which maize and vetch plants were cultivated in a low metal contaminated soil and after three weeks of growth, a negative effect on the length of shoots and roots was observed. The biomass of the plant seedlings was significantly smaller in the metal containing soil in comparison to the other control. This further gave credence to the fact that the unspiked soil fared better than the spiked one in this research. Nevertheless, *Zea mays* plants from the two controls of this experiment (unspiked i.e. Control A) and (spiked i.e. Control B) showed better growth than those of the test groups (5%, 10% and 20%) w/w crude oil contaminated soils.

Additionally, it was observed in Figs. 1 and 2 that 20% w/w (PHC) soils recorded the highest Zea *mays* height among the crude oil contaminated soils, followed by 10% w/w and the least was 5% w/w crude oil contaminated soil. Hence, the plant height progression was 20%>10%>5% (PHC) soils, respectively. The result of the present work differs from those of earlier researchers. It had also been observed that tallness in plant might not be associated with wellness considering the fact that deficiency of proteins in the protoplasm as well as non formation of other coenzymes necessary for proper stem development is due to lack of some mineral salts present in the soil (calcium, sulphur and phosphorus as well as the trace elements) which could cause the stems to become slender and make the lower part of the leaves to become mottled as well as cause weedy growth in some plants with formation of purple colour in leaves (Ramlingan, 2001). These were observed in this research, that even though Zea *mays* fromthe 20% (PHC) soils had taller plants, their stem developments and leaf breadth were poorer than those of 10% and 5% (PHC) soils and they also had mottled and purple leaves.

Moreover, this work recorded germination of 1 out of 12 seeds planted among the 5% w/w crude oil contaminated soil, hence the reason for nursery transplants into the various contaminated soils where germination did not take place. All the *Zea mays* grown on the contaminated soils expressed stunted growth. The 20% w/w and 10% w/w crude oil contaminated soils showed plants with purple veins while the 5% w/w showed yellowing of leaves after 4 weeks of germination. Again, it is possible that deficiencies of various minerals in the soil were responsible for this colouration in the leaves as observed in this experiment. When a soil is polluted with crude oil, plant growth becomes adversely affected for some time and after a period the hydrocarbons becomes decomposed and are converted to soil organic nutrient (matter) which improves the content of the soil. However, this could take a long period of time under which the soil may remain unproductive for agricultural purposes (Plice, 1948).

The highest value (as seen in Figs. 5 and 6, as well as Figs. 3 and 4) of the measured leaf length and breadth showed that among the various treatments there was a mean significant difference (P<0.05) in both the leaf length as well as breadth of the various groups, respectively. The highest value (as illustrated in Figs. 3, 4, 5, and 6) belongs to control A (unspiked) soil, followed by the spiked soil for the first 6 days in the breadth of the leaf. However, the mean leaf breadth of both controls became equal from the 7^{th} to the 14^{th} day but there was a consistent increase in leaf length throughout the 14 days in which they were measured, see Fig. 3. Moreover, the mean value of control A (unspiked soil) leaf length andbreadth was more than those of control B (spiked soil) leaf length and leaf breadth (Fig. 4).

Among the test soil samples 20% w/w of crude oil contaminated soil had plants which had total group higher mean leaf length but lesser leaf breadth (Figs. 4 and 6) followed by 5% w/w crude oil contaminated soil mean leaf length andhigher mean leaf breadth. The least value of mean leaf length and breadth (Figs. 4 and 6) however was observed in 10% w/w PHC soil. Among the test samples (simulated contaminated soil) therefore, the mean of the leaf length and breadth of *Zea mays* of the petroleum hydrocarbon (PHC) contaminated soils were statistically different (P<0.05). This observation was unusual possibly due to the nature of the microorganisms indigenous to the Nsukka soil as well as the ability of agents of biodegradation such as sunlight, temperature, rainfall etc which causes the crude oil to degrade faster. Perhaps it could be as a result of deficiency of vital minerals and trace elements such as sulphur and phosphorus which are responsible for coenzyme synthesis as a result there was higher leaf length and plant height in the highest crude oil contaminated soil when compared to the other two soils with lower crude oil contamination.

Conclusion

Conclusively, there was reduction in the plant length, leaf length and breadth of all *Zea mays* plant cultivated on the crude oil contaminated soil. The character of these measured growth indices (*Zea mays* grown in contaminated soil) showed that they were half the value of the controls. The results are in agreement with similar work carried out by Ayotamuno and Kogbara (2007) in which yield from contaminated soils were about 38% of those of controls. Leaf burn (leaf mottling) as well as yellowing/purple colouration was also observed during the period of the study in the *Zea mays* of the test soils while those of the controls were green all through. This also was observed elsewhere (Ayotamuno and Kogbara, 2007).

The summary of the *Zea mays* growth index on crude oil contaminated soil is that there is an inhibition in seed germination and plant growth which is dependent on the concentration of the crude oil contaminated soil (Odjegba and Sadiq, 2002). The Nsukka soil like most tropic soils might record faster crude oil degradation ability when contaminated with crude oil. Generally, however, crude oil contaminated soils had negative impact on the growth of plants particularly *Zea mays.*

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Conflict of Interest

Authors wish to declare that there is no conflict of interest in this work.

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