Effect of crude oil and palm bunch ash on maize growth

Emmanue Ogboma Dania*, Temitayo Fayehun, Osemhengbe Ruth Akhabue
Biochemistry Department, University of Benin Nigeria, Benin City, Nigeria

Abstract

Objective: To investigate the effect of different crude oil fractions (whole crude and water soluble fraction) at 2% contamination (98% distilled water) and the effect of 2 g of palm bunch ash (PBA) on the phytotoxicity of crude oil fraction on growth parameters such as percentage of seedling emergence, plant height, number of leaves, length of root, length of radical and leaf area in maize (Zea mays).

Methods: A total of 180 bags containing 500 g of loamy soil each were used for this study, of which 30 bags containing loamy soil each served as control, 60 bags of soil were added each 2% crude oil fraction and 60 bags of soil were added each 2% crude oil fraction and 2 g PBA each, while 30 bags of soil contained each 2 g of PBA only. The maize grown on the soil was harvested after 7, 14 and 21 days of seedling emergence and assessed for growth parameters.

Results: The growth parameters (plant height, length of root, length of radicle, number of leaves, and leaf area) in maize were significantly reduced in the crude oil fraction treatment (P ≤ 0.05). The treatment containing PBA was found to have significant improvement compared to the crude oil fraction contaminated treatment.

Conclusions: The study has revealed the deleterious effect of crude oil at 2% on maize and its effect was ameliorated using PBA.

1. Introduction

Nigeria is one of the oil producing countries with exportation of crude oil being the mainstay of her economy[1]. Crude oil is a colloidal mixture of different hydrocarbons and non-hydrocarbon components. Crude oil pollution is an inevitable phenomenon in oil producing and consuming areas worldwide[2]. It stems from human error, accidental discharge and other sources[3]. The severity of oil pollution varies with the quantity, plant species, age of the plant, adequacy of the responses as well as other factors[4]. Crude oil poses serious threats to organisms and farmland[5]. Many studies have been carried out and reported the effect of crude oil on growth and performance of plants which makes the soil unsatisfactory for plant growth[6-8]. Although crude oil is immiscible with water, there is a small portion of it called the water soluble fraction (WSF) that can dissolve in water. The toxicity of this fraction has also been reported by Olubodun and Eriyamremu[1] at different percentages of contamination.

Palm bunch ash (PBA) is obtained from the empty fruit bunches of Elaeis guineensis (Arecales). It has been reported that it mainly contains potassium carbonate and potassium hydroxide[9] and is recognized as a 100% organic fertilizer, serving as a cheap source of potassium oxide[10,11]. Research has been carried out on how bioremediation can be carried out naturally, or by the use of nutrients (organic or inorganic fertilizer) or by the use of chemical or mechanical means. Anderson et al.[12] and Onyelucheya et al.[10] reported that the rate of bioremediation varies with the soil and the kind of environment, compound to be degraded and concentration of the compound in the environment.

Maize (Zea mays) is a major staple food grown and consumed in Nigeria. It is grown in most agro-ecological areas, especially areas where oil industrial activities are predominant in the Niger Delta[13]. The effect of crude oil and its WSF on growth parameters like height, root length and leaf area of maize at various percentages of contamination has been reported by Olubodun and Eriyamremu[1]. Therefore, the aim of this study was to evaluate the phytotoxicity response of maize to crude oil and its WSF at 2% contamination and investigate the reduction in phytotoxicity following PBA stimulated remediation.

2. Materials and methods

Garden soil used for this study was collected from the Nursery Unit of the Department of Botany, University of Benin, Nigeria.
The empty palm bunches were obtained from palm oil mill at Oluku in Ovia North East Local Government, Edo State. The crude oil was obtained from Warri Refining and Petrochemical Company, Warri, Delta State, Nigeria. The maize seeds were bought from Ediaken Market in Benin City and identified at the Department of Plant Biology and Biotechnology, University of Benin.

2.1. Methods

The maize seeds were placed in a beaker containing water and stirred. Those that did not float were regarded as viable seeds. The garden soil of pH 6.55 was weighed into 180 polythene bags with each bag containing 500 g of soil. A portion of the crude oil was fractionated by the method of Anderson et al.[12] into WSF and WC and water insoluble fraction by putting 200 mL of crude oil and 400 mL of water in 1 L conical flask was constantly stirred for 48 h. The WSF was then obtained using separating funnel. The oil palm empty fruit bunches were sun-dried for one week before they were ashed at 700 °C.

2.2. Soil treatment

The soil was divided into six treatments with each treatment having 30 polythene bags with 500 g of soil (Table 1). Whole crude (WC), WSF, whole crude and ash (WCA) and water soluble fraction and ash (WSFA) treatment were given 2% PBA. The contaminated soil was then obtained using separating funnel. The oil palm empty fruit bunches were sun-dried for one week before they were ashed at 700 °C and in air for 24 h. The soil was divided into six treatments with each treatment having 30 polythene bags with 500 g of soil (Table 1).

2.3. Planting seeds

Four viable seeds were sown in the soil bag with a depth of 1–2 cm. The time and number of seedling emerged from each were noted and the percentage of seedling emergence in each treatment was calculated. The emerged seedlings were harvested at Day 7, Day 14 and Day 21 to assess growth parameters. Data for each parameter were analyzed separately using One-way ANOVA followed by Duncan’s multiple range test. P ≤ 0.05 was considered statistically significant.

### Table 1

| Treatments | Number of bags | Contamination (%) | PBA (g) |
|------------|----------------|-------------------|---------|
| Control    | 30             | 0                 | 0       |
| WC         | 30             | 2                 | 0       |
| WSF        | 30             | 2                 | 0       |
| CA         | 30             | 0                 | 2       |
| WCA        | 30             | 2                 | 2       |
| WSFA       | 30             | 2                 | 2       |

CA: Control and ash.

### Results

Contamination of the soil with crude oil and its fraction significantly reduced all the growth indices measured by this study (Tables 2–5). The percentage of emergence of maize plants in crude oil contaminated soil (WC and WSF) decreased compared to the control with WC having the least value (Table 2). Plant height, number of leaves, length of radicle and leaf area were significantly affected by the oil treatment when compared with seedlings grown in the uncontaminated soil (P ≤ 0.05).

### Table 2

Effect of different fractions of crude oil contamination and PBA on maize germination.

| No. of seeds planted/bag | Control | WC | WSF | CA | WCA | WSFA |
|--------------------------|---------|----|-----|----|-----|------|
| Percentage of seedling emergence | 100 | 65 | 80 | 100 | 72 | 88 |

### Table 3

Effect of different fractions of crude oil contamination and PBA on growth parameters of maize at Day 7 after germination.

| Growth parameters | Control | WC | WSF | CA | WCA | WSFA |
|-------------------|---------|----|-----|----|-----|------|
| Plant height      | 33.0 ± 0.3 | 18.9 ± 0.2 | 21.3 ± 0.4 | 33.1 ± 0.1 | 23.0 ± 0.3 | 26.0 ± 0.1 |
| Number of leaves  | 3.0 ± 0.2   | 3.0 ± 0.1   | 3.0 ± 0.2   | 3.0 ± 0.4   | 3.0 ± 0.3   | 3.0 ± 0.4   |
| Length of radicle | 4.0 ± 1.1   | 3.9 ± 0.2   | 3.9 ± 0.1   | 4.0 ± 1.2   | 4.0 ± 0.1   | 4.0 ± 1.7   |
| Leaf area         | 41.0 ± 0.3  | 20.5 ± 0.6  | 25.2 ± 0.2  | 42.0 ± 0.5  | 28.5 ± 1.2  | 32.0 ± 0.1  |

Each value is the mean of 10 replicates. Values in rows followed by the different letters are significantly different at P ≤ 0.05 according to Duncan’s multiple range tests.

### Table 4

Effect of different fractions of crude oil contamination and PBA on growth parameters of maize at Day 14 after germination.

| Growth parameters | Control | WC | WSF | CA | WCA | WSFA |
|-------------------|---------|----|-----|----|-----|------|
| Plant height      | 65.5 ± 0.8 | 37.1 ± 0.3 | 42.1 ± 0.3 | 66.0 ± 0.2 | 46.1 ± 1.1 | 53.2 ± 0.5 |
| Number of leaves  | 6.1 ± 0.2   | 5.8 ± 0.1   | 5.8 ± 0.1   | 6.0 ± 0.3   | 6.0 ± 0.2   | 6.0 ± 0.2   |
| Length of radicle | 40.0 ± 1.2  | 25.2 ± 0.3  | 31.0 ± 1.1  | 41.1 ± 0.2  | 29.3 ± 1.0  | 33.1 ± 1.6  |
| Leaf area         | 60.3 ± 1.5  | 43.2 ± 1.0  | 46.0 ± 0.1  | 64.0 ± 0.2  | 53.2 ± 1.0  | 58.2 ± 0.3  |

Each value is the mean of 10 replicates. Values in rows followed by the different letters are significantly different at P ≤ 0.05 according to Duncan’s multiple range tests.

### Table 5

Effect of different fractions of crude oil contamination and PBA on growth parameters of maize at Day 21 after germination.

| Growth parameters | Control | WC | WSF | CA | WCA | WSFA |
|-------------------|---------|----|-----|----|-----|------|
| Plant height      | 56.1 ± 0.9 | 45.3 ± 3.0 | 54.0 ± 1.4 | 77.0 ± 1.1 | 62.0 ± 0.3 | 63.1 ± 1.5 |
| Number of leaves  | 7.2 ± 0.1   | 5.9 ± 0.3   | 6.0 ± 0.1   | 7.0 ± 0.1   | 6.1 ± 0.2   | 7.0 ± 0.3   |
| Length of radicle | 56.2 ± 0.5  | 39.1 ± 0.1  | 48.5 ± 1.2  | 56.0 ± 0.3  | 43.4 ± 1.5  | 53.1 ± 1.1  |
| Leaf area         | 60.1 ± 1.5  | 32.1 ± 0.1  | 56.0 ± 9.0  | 74.0 ± 1.0  | 62.3 ± 0.3  | 68.3 ± 0.2  |

Each value is the mean of 10 replicates. Values in rows followed by the different letters are significantly different at P ≤ 0.05 according to Duncan’s multiple range tests.

4. Discussion

The seedling emergence was not significantly different in WC and WSF from the control 7 days post germination. However, in 14 and 21 days post germination, LN of maize in WC and WSF was significantly reduced compared to the control with WSF having the lowest value. This same trend was observed in plant height, length of radicle, length of root and leaf area (Tables 4 and 5). Another visible symptom was the yellowness of leaves in WC and WSF treatment.
At 2% contamination, there was a negative effect on the growth parameters of maize.

The yellowness of leaves and reduction of growth parameters of the maize could be due to nutrient immobilization, as oil pollution has been reported to cause unavailability of essential nutrients to the young seedling[14]. The WSF also could have been absorbed alongside soil water, thereby accumulating in tissues such as chloroplast, xylem and phloem affecting the photosynthetic process and movement of essential materials in the plant[4]. This would have caused a general reduction in the growth parameters being considered by this study.

The effect of PBA in enhancing bioremediation of crude oil and its fraction on phytotoxicity shows that there is no significant difference in the number of leaves 7 days post germination in all treatment and control. In WCA and WSFA, there was a significant difference in plant height, length of root, length of radicle and leaf area compared to their corresponding treatment without PBA. In 14 and 21 days post germination, there was a consistent improvement in plant height, number of leaves, length of root, length of radicle and leaf area of toxic soil treated with PBA compared with crude oil treated soil only. The improvement in growth parameters of the maize was a result of improvement in soil condition following the application of PBA. The growth parameter of the CA treatment did not show any significant difference compared with the control. PBA has been reported to contain potassium carbonate and potassium hydroxide which have no toxic effect to the soil or maize[9]. Onyelucheya et al.[10] reported the specific growth rate of microbes increased with the addition of PBA at low level of contamination, hence the rate of breakdown of the crude oil and its fractions increased. Udoetok[15] reported that the presence of essential compounds such as phosphate, chloride, nitrate and sulphate in PBA could enhance the hydrocarbon degrading potential of hydrocarbon degraders in the soil.

The improvement in the growth parameters of maize as reported in this study is consistent with the previous report of improved germination and plant growth after remediation[16,17]. With the use of PBA enhanced preferential remediation[10], crude oil toxicity effect can be mitigated and crop cultivation is possible in exposed land. People living in underprivileged conditions, especially in Africa where there is a continuous incidence of crude oil contamination of the soil leading to low yield of maize, can improve their productivity by applying PBA to their contaminated farmland, which can be harnessed locally from their surroundings.

Conflict of interest statement

We declare that we have no conflict of interest.

References

[1] Olubodun OS, Eriyamremu EG. Effect of different crude oil fractions on growth and oxidative stress parameters of maize radicle. Int J Plant Soil Sci 2013; 2(1): 144-54.

[2] Agbogidi OM, Eshegbeyi OF. Performance of Dacryodes edulis (Don. G. Lam H. J.) seeds and seedlings in a crude oil contaminated soil. J Sustain For 2006; 22: 1-13.

[3] Agbogidi OM, Ayelo E. Germination of African oil bean (Pentaclethra macrophylla, Benth.) seeds grown in crude oil polluted soil. In: Onyekwelu J, Adekunle VAJ, Oko DO, editors. Proceedings of the 2nd biennial national conference of the forests and forest products society. Akure: Federal University of Technology; 2010, p. 105-11.

[4] Agbogidi OM. Effects of crude oil contaminated soil on biomass accumulation in Jatropha curcas L. seedlings. J Ornam Hort Plants 2011; 1(1): 43-9.

[5] Vwioko DE, Anoliefo GO, Fashemi SD. Metal concentration in plant tissues of Ricinus communis L. (castor oil) grown in soil contaminated with spent lubricating oil. J Appl Sci Environ Manag 2006; 10(3): 127-34.

[6] Ekpo IA, Agbor RB, Okpako EC, Ekanem EB. Effect of crude oil polluted soil on germination and growth of soybean (Glycine max). Ann Biol Res 2012; 3(6): 3049-54.

[7] Okolo JC, Amadi EN, Odu CTI. Effects of soil treatments containing poultry manure on crude oil degradation in a sandy loam soil. Appl Ecol Environ Res 2005; 3(1): 47-53.

[8] Onomosun G, Markson AA, Mbanaso O. Growth and anatomy of Amaranthus hybridus as affected by different crude oil concentrations. Am Eurus J Sci Res 2008; 3(1): 70-4.

[9] Taiwo OE, Osinowo FA. Evaluation of various agro-wastes for traditional black soap production. Bioresour Technol 2001; 79(1): 95-7.

[10] Onyelucheya OE, Osoka EC, Onyelucheya CM. Modeling palm bunch ash enhanced bioremediation of crude-oil contaminated soil. Int J Sci Eng Investig 2013; 2(13): 8-12.

[11] Salim B. Palm bunch ash as organic fertilizer. 2007. [Online] Available from: www.forum.agriscape.com/thread/1720015/1 [Accessed on 25th July, 2016]

[12] Anderson JW, Neff JM, Cox BA, Tatem HE, Hightower GM. Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish. Mar Biol 1974; 27(1): 75-88.

[13] Agbogidi OM, Eruotor PG, Akparobi SO. Effects of crude oil levels on the growth of maize (Zea mays L.). Am J Food Technol 2007; 2(6): 529-35.

[14] Anoliefo G, Isikhuemen O, Ohimain E. Sensitivity studies of the common bean (Vigna unguiculata) and Maize (Zea mays) to different soil types from the crude oil drilling site at Kutchari, Nigeria (7 pp). J Soils Sediments 2006; 6(1): 30-6.

[15] Udoetok IA. Characterization of ash made from oil palm empty fruit bunches (oefb). Int J Environ Sci 2012; 3(1): 518-24.

[16] Saterbak A, Toy RJ, McMain BJ, Williams MP, Dorn PB. Ecotoxicological and analytical assessment of effects of bioremediation on hydrocarbon-containing soils. Environ Toxicol Chem 2000; 19(11): 2643-52.

[17] Wang X, Bartha R. Effects of bioremediation on residues, activity and toxicity in soil contaminated by fuel spills. Soil Biol Biochem 1990; 22(4): 501-5.