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Original Research Article

Performance of Cassava (*Manihot esculenta* Crantz) as Affected by Crude Oil Contamination of Soil

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ABSTRACT
Cassava, a staple crop globally and particularly in Nigeria, is widely cultivated for its significant contribution to food security. However, crude oil exploration has led to widespread contamination of farmlands, resulting in substantial losses for farmers. This research examined the effects of crude oil contamination on cassava cultivation in Nigerian soil. Cassava stem cuttings were sourced from local farms in Abraka, Delta State, Nigeria. Crude oil samples were obtained from the Nigerian National Petroleum Corporation (NNPC). The soil was artificially contaminated with varying levels of crude oil (ranging from 30, 60, 90 and 120 ml), while a separate, uncontaminated soil sample served as the control group. Plant growth parameters, including germination rate, plant height, leaf number, and leaf area, were evaluated. The results showed that crude oil contamination significantly ($P < 0.05$) delayed germination, reduced germination rate and percentage, and impaired plant growth. The effect being oil level dependent, the highest crude oil treat (120 ml) had the most detrimental effects, with a germination percentage of 32%. Conversely, unpolluted soil had the highest plant height (24.8 cm) and leaf area (178.52 cm^2) across the 12-week study period. This study highlights the need for sustainable practices to mitigate crude oil contamination in agricultural areas. Findings from the study indicate that crude oil contamination significantly impact cassava ability to grow leading to reduced productivity and food security concerns Recommendations include exploring crude oil in areas far from farmlands, implementing effective bioremediation strategies, and enforcing rigorous cleanup policies to protect the environment and ensure food security.

CITATION
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INTRODUCTION

Cassava (Manihot esculenta Crantz), a staple crop in the Euphorbiaceae family, plays a vital role in Africa and Asia due to its nutrient-rich storage roots and leaves (International Institute of Tropical Agriculture [IITA], 2009). The tuber is an excellent source of carbohydrates, calcium, vitamins B and C, and essential minerals like potassium, zinc, iron, and phosphorus. In Central Africa, cassava leaves serve as a crucial protein source for human consumption, particularly in countries like Burundi, Congo, and the Central African Republic. While cassava may not be the primary staple in every country, it is a fundamental food source for many populations. According to the FAO, global cassava production experienced significant growth, increasing from 97 million tons in 1999 to 226 million tons in 2007 (FAO, 2007). Africa dominates global production, accounting for approximately 94% of total output, with countries like Nigeria, Ghana, Benin, and Togo leading the way (FAO, 2007). Beyond its role as a food source, cassava has industrial applications, including the production of sweeteners, glues, textiles, paper, biodegradable materials, and pharmaceuticals (IITA, 2009). Its potential for biofuel production through starch fermentation also offers a promising alternative to petrol fuel, contributing to reduced pollution.

Nigeria's cassava yield lags behind the global average, with 10.6 tons per hectare recorded in 2002, significantly trailing countries like Barbados, which achieved 27.3 tons per hectare that same year. Nigeria's high production volumes are primarily attributed to extensive land cultivation, rather than optimized yields. To satisfy domestic demand, Nigerian cassava productivity must surpass the world average. A key factor contributing to the subpar yields is the widespread adoption of low-yielding, disease-susceptible local varieties among Nigerian farmers (Mazzalira *et al*., 2013; Njoku *et al*., 2015). Successful commercial cassava production hinges on access to high-quality stem cuttings that combine disease resistance, particularly against cassava mosaic disease, and resilience to adverse environmental conditions like drought, with improved yields (Adjata *et al*., 2013). Cassava is primarily propagated through vegetative means using stem cuttings, but some varieties still utilize sexual reproduction. In traditional farming systems, farmers often permit volunteer seedlings to emerge, and then select promising individuals for clonal propagation, a practice known as clonal selection (Elias *et al*., 2001). Crude oil hydrocarbons are a prevalent group of persistent organic pollutants (POPs) that pose significant environmental concerns (Abdollahzadeh *et al*., 2019; Odukoya *et al*., 2019; Gamage *et al*., 2020). The toxic effects of petroleum hydrocarbons on living organisms are well-documented, with studies highlighting their mutagenic and carcinogenic properties (Ma *et al*., 2018; Rusin *et al*., 2018). The slow degradation rate of oil and oil products in the environment leads to their accumulation and increased concentration in environmental matrices, including soil. Once crude oil enters the soil, it can alter its structure, disrupt the air-water balance (Abdollahzadeh *et al*., 2019), and modify its physicochemical properties (Achuba, 2014). This can inhibit microbial growth (Abdollahzadeh *et al*., 2019), disrupt soil enzymatic activity, and negatively impact terrestrial and soil mesofauna (Peretiemo-Clark and Achuba, 2007), as well as plant growth and development (Odukoya *et al*., 2019; Rusin *et al*., 2020). The adverse effects of crude oil on plant growth and development can be attributed to several factors. Firstly, the absorption of toxic petroleum molecules by plants can alter plasma membrane permeability and structure, modify parenchyma tissue shape and size, reduce intercellular space in stem and root cortex, and inhibit root meristem mitotic activity (Bellout *et al*., 2016). Secondly, insufficient aeration due to air displacement by crude oil can lead to root stress and reduced water availability (Ather *et al*., 2016). Furthermore, oil pollution can minimize organic matter availability and reduce mineral nutrient levels, including sodium, phosphates, potassium, sulfates, and nitrates (Otitoju *et al*., 2017; Achuba and Ja-anni, 2018).

The impact of oil pollution on plants is multifaceted, affecting physiological, biochemical, and molecular processes. Despite its significance, the effects of oil contamination on photosynthesis are not well understood. Recent studies have shown that crude oil pollution can impair photosynthetic activity and reduce chlorophyll content in plants (Ather *et al*., 2016). Additionally, plants growing in oil-polluted soil often exhibit decreased starch metabolizing enzyme activity, as well as reduced total carbohydrate, protein, and amino acid content (Al-Hawas *et al*., 2012). One of the most detrimental effects of oil pollution on plants is oxidative stress, which triggers the formation of reactive oxygen species (ROS) with high oxidizing capacity. These ROS, including superoxide radicals (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radicals (OH), can damage cell membranes, disrupt transport processes, and inhibit growth (Zaid *et al*., 2019). This study investigates the impact of crude oil pollution on cassava (*Manihot esculenta)*, a staple crop in Nigeria. Understanding the effects of oil pollution on cassava growth and development is crucial for developing strategies to mitigate these impacts and ensure food security.

MATERIALS AND METHODS

Study site

The study site is Abraka, Delta State. Between latitudes 5°00 and 6°30'N and longitudes 0°00 and 6°45'E, roughly, is where Delta State is located. Its total land area is 16,842 square kilometers. Delta State is bordered to the north by Edo, to the northwest by Ondo, to the east by Anambra, and to the southeast by Bayelsa and the Rivers. The Bight of Benin's 160 km of coastline can be found on its southern flank. Abraka is located in Latitude 5.74745° or 5° 44' 51" north and Longitude 6.12794° or 6° 7' 41" east (Efe and Aruegodore, 2003). Figure 1 is a map of Abraka. The experiment was carried out in a screen house at the Botanical garden of the Department of Botany, Delta State University, Abraka, Delta State, Nigeria. The map of the study area is shown in Figure 1.

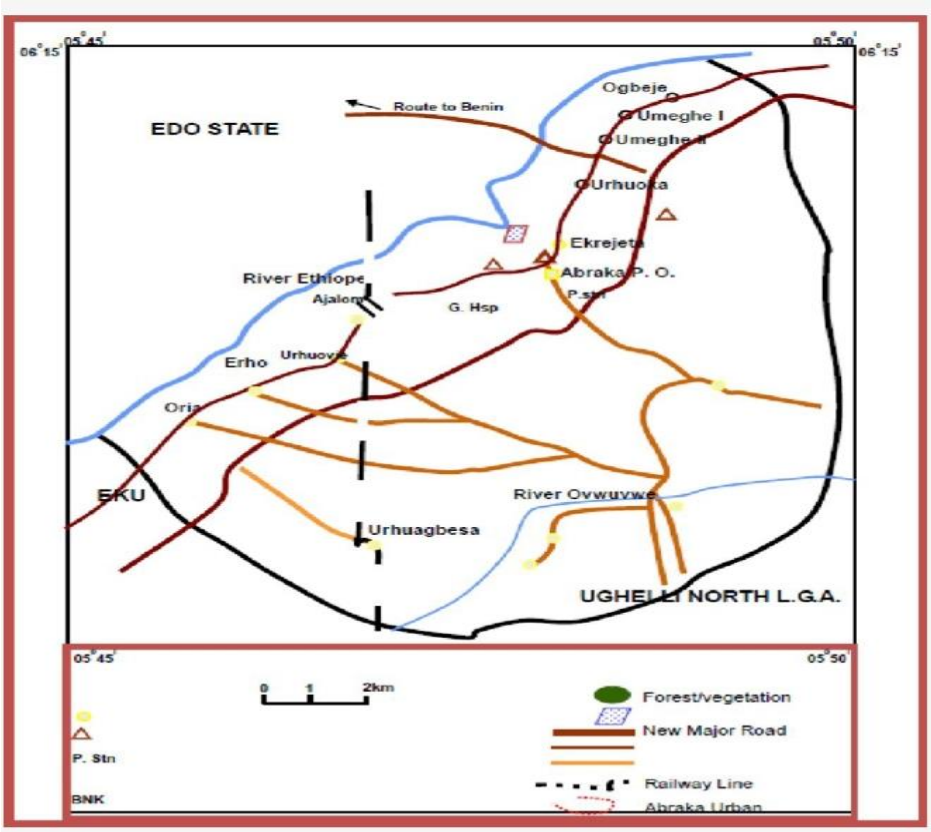

Figure 1: Map of Abraka (Source: Efe *et al*., (2003))

Source of Materials

The top loamy soils used for the study were obtained from the Delta State University Botanical Garden. The crude oil was obtained from Nigerian National Petroleum Corporation, Warri, Delta State. The cassava cuttings were obtained from local farmers in Abraka, Delta State, Nigeria.

Soil Preparation and Treatment

For the experiment, 2kg of soil was treated with 0 (control), 30, 60, 90 and 120 ml crude oil and replicated four (4) times. The oil-soil mixture were mixed thoroughly and left for 2 days to allow for proper mixing. Another pot with no crude oil (0 ml) served as the control. The cassava cuttings were planted into the experimental pots and left for a total duration of 12 weeks (3 months). This set up was arranged in a Randomized Complete Block Design (RCBD).

Control = Soil (2 kg) + crude oil (0 ml)
Treatment 1 (T1) = Soil (2 kg) + crude oil (30 ml)
Treatment 2 (T2) = Soil (2 kg) + crude oil (60 ml)
Treatment 3 (T3) = Soil (2 kg) + crude oil (90 ml)
Treatment 4 (T4) = Soil (2 kg) + crude oil (120 ml)

Measurement of Plant Growth Parameters

Growth parameters including days to germination, rate of germination and percentage germination were observed. Other growth characteristics measured include plant height, number of leaves and leaf area.

Measurement of Days to Germination

The days to germination were measured by visual observation of the first foliage leaves to emerge from the cuttings.

Measurement of rate of germination and germination percentage

Rate of germination of cassava was determined by number of cuttings planted divided by the total number of cuttings planted and calculated using the formula.

$$GP = \frac{\text{Number of stem cuttings}}{\text{Total number of cuttings planted}} \times 100$$

Height of the Plant

The heights of the plants were measured daily using a measuring tape. The height was measured from the tip of the leaf to the soil level.

Number of Leaves

The numbers of the leaves were counted by visual counting and this was done daily for seven (7) days.

Measurement of leaf area

Leaf area was obtained by measuring the length and width of the maximum leaf and multiplying by the correlation factor which is 0.75 following the procedure of Agbogidi *et al*. (2005).

Leaf Area = L x B x 0.75

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) where significant differences exist, treatment means were compared at P < 0.05 significant level using Duncan's New Multiple Range Tests (DMRT).

RESULTS AND DISCUSSION

The germination experiment results are summarized in Table 1. Cassava cuttings planted in control soils exhibited optimal germination performance, achieving 100% germination rate and sprouting within 2.50 ± 0.14 days. Similarly, soils contaminated with 30 ml crude oil effluents showed no adverse effects, with 100% germination rate and a germination period of 4.50 ± 0.23 days. However, significant declines in germination rates and delayed sprouting were observed in treatments with higher oil concentrations: 60 ml (5.01 ± 1.12 days, 55% germination rate), 90 ml (6.20 ± 1.35 days, 32% germination rate), and 120 ml (8.54 ± 0.52 days, reduced germination rate).

Table 1: Germination parameters of cassava stems as influenced by crude oil on soil

Treatment (ml)	Days to germination	Rate of germination	Germination percentage
0	4.50 ± 0.14	100^a	100^a
30	5.50 ± 0.23	100^a	100^a
60	5.81 ± 1.12	67^b	67^b
90	6.20 ± 1.35	55^c	55^c
120	8.54 ± 0.52	32^d	32^d

Values are presented in Mean. Values with different superscript are significantly different using Duncan's Multiple Range Tests (DMRT).

Table 2: Number of leaves of cutting grown in different levels of crude oil in soil

Treatment (ml)	Number of leaves/weeks after planting												Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
0	17	21	34	52	69	76	86	89	94	96	98	112	73^c
30	0	12	31	47	58	65	69	84	85	94	96	109	66^b
60	11	7	41	32	37	37	32	29	30	29	23	24	30^b
90	2.0	8	23	26	28	37	47	38	40	41	41	41	28^d
120	0.0	8	18	9.7	33	27	29	29	29	18	18	0.0	20^a

Values are presented in Mean. Values with different superscript are significantly different using Duncan Multiple Range Tests (DMRT).

Table 3 presents the impact of crude oil on plant height. The results indicate that stem cuttings cultivated in the control soil achieved the maximum height of 24.8 cm, closely followed by those exposed to 30 ml crude oil, which reached a height of 23.9 cm. In contrast, the cuttings subjected to the highest crude oil treatment (120 ml) exhibited the shortest height, measuring only 12.8 cm.

Table 3: Plant height of cutting grown in different levels of crude oil

Treatment (ml)	Height/weeks after planting												Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
0	5.4	6.6	11.4	14.7	15.7	18.5	19.7	21.5	22.9	23.8	24.2	24.8	18.01^a
30	0.2	2.6	9.9	14.4	15.2	16.1	16.8	17.9	18.9	22.9	23.2	23.9	15.87^d
60	2.7	4.1	7.7	11.9	14.6	15.4	16.4	17.6	18.8	20.1	20.4	21.0	14.26^b
90	0.8	2.7	7.4	9.0	10.1	11.4	12.6	14.6	14.8	14.6	17.6	18.9	11.92^b
120	0.0	0.5	6.2	8.7	9.7	11.0	11.7	12.3	12.6	12.8	12.8	12.8	8.72^a

Values are presented in Mean. Values with different superscript are significantly different using Duncan Multiple Range Tests (DMRT).

The leaf area of the leaves of *Manihot esculenta* across 12 weeks is shown in Table 4. The leaf area across all treatments shows steady increase. Treatment 1 showed larger leaf area across all treatments while the treatment with the least area of leaf was observed in plants grown in 120 ml of crude oil.

Table 4: Leaf area (cm^2) of cuttings as influenced by crude oil

Leaf area/weeks after planting	Concentration of crude oil (ml)				
	0	30	60	90	120
Week 1	4.69	0.07	0.26	0.21	0.00
Week 2	36.22	31.04	18.62	10.65	3.48
Week 3	75.12	68.24	36.48	19.49	13.41
Week 4	88.87	73.72	48.75	28.72	21.39
Week 5	94.92	79.42	54.52	38.02	26.38
Week 6	108.12	86.88	61.22	46.63	30.50
Week 7	122.86	93.98	67.93	56.81	33.13
Week 8	135.92	101.25	76.31	68.89	36.18
Week 9	155.17	115.75	92.66	81.35	39.65
Week 10	160.39	133.23	104.15	94.07	40.47
Week 11	168.19	143.38	113.26	105.31	40.47
Week 12	178.52	156.79	125.69	117.16	0.00
Means	110.42^{a}	90.31^{b}	66.65^{c}	55.61^{d}	23.75^{e}

Values are presented in Mean. Values with different superscript are significantly different using Duncan's Multiple Range Tests (DMRT).

Discussion

The findings revealed a notable decline in cassava plant development, encompassing germination indices, days to germination, germination percentage, germination rate, stem height, leaf number and leaf area, as crude oil levels increased. This suggests that crude oil in soil has detrimental impacts on cassava growth and productivity. The delayed germination observed in polypots contaminated with 60 ml and 90 ml of crude oil further underscores the adverse impacts crude oil have on cassava development. Similar delays in germination had been previously reported for maize exposed to crude oil (Agbogidi *et al*., 2006) and spent engine oil (Uhegbu *et al*., 2012), highlighting the potential for petroleum-based contaminants to impede seedling emergence of crop plants. The adverse impacts crude oil contamination have on plant growth are not unique to cassava. Previous studies have reported similar growth reductions in tomato (Falodun *et al*., 2011), soybean (Gandahi and Hanafi, 2014), and spinach (Loh *et al*., 2019) when exposed to varying levels of crude oil.

Notably, the delayed germination and growth can be caused by alterations caused by soil following crude oil contamination. The heavy metal concentration and other substances in crude oil can disrupt soil properties, affecting plant development. Specifically, the low germination percentage in cuttings grown in 120 ml of crude oil may be due to the clogging of stems, which can impede respiratory and metabolic processes, delaying sprouting. Similar findings have been reported for other plant species, including okra, soybean, and cowpea and pumpkin, when exposed to crude oil and its products (Agbogidi and Nweke, 2005; Agbogidi *et al*., 2006; Agbogidi, 2010). The buds may have come into contact with crude oil, causing clogging and delaying sprouting. This highlights the potential for crude oil contamination to have far-reaching consequences for plant vegetative growth and morphological development. The diminished growth parameters observed in plants cultivated in contaminated plots, compared to those grown in uncontaminated soils, can be linked to disruption of soil microflora and the depletion of essential macro and micronutrients. This disruption could have compromised soil fertility, hindering optimal plant growth.

Previous studies have documented similar findings in various plant species, including tomato (Nizor *et al*., 2018), oil palm (Maliki *et al*., 2020), and Brazilian spinach. Agbogidi *et al*. (2007) emphasized that oil contamination in soil affects all soil properties, including its physical, chemical, and biological characteristics.

The presence of oil particles in the soil can displace oxygen, reducing the available space for soil fauna and microflora to thrive. This alteration can have cascading effects on soil health, ultimately impacting plant growth and productivity. This observation is supported by the findings of Okwute and Isu (2007) and Chinyere *et al*. (2018), who also reported on the detrimental consequences of oil spills on soil properties and plant growth.

CONCLUSION

This study demonstrates that crude oil spillage substantially impairs cassava's germination and growth, ultimately compromising productivity and contributing to food insecurity. The study also established the effect is oil level dependent. To mitigate these effects, it is recommended that thorough environmental monitoring and remediation be conducted prior to cultivating cassava in areas contaminated with crude oil. Furthermore, educating farmers and raising environmental awareness are crucial for promoting sustainable agricultural practices.

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