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The Effect of Hydrocarbon Pollution on Niger Delta Root Crops: A Case Study of Cocoyam [Colocasia Esculenta]

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Abstract*: *This paper investigates effects of re-occurring oil spillages on cocoyam, Colocasia esculenta (L.). It studies changes in petiole lengths, leaf blades, chlorophyll concentrations in leaves, and PAH and BTEX concentrations in tubers for three generations under diverse conditions. 8 10-gallon grow bags were used: Grow bags 5–8 were treated with a controlled quantity (4 L/cubic metre) of liquid crude hydrocarbon in the months of June 2019–2021; with 2 replications, after a 2-3-day interval within a week. In grow bags 3, 4, 7, and 8, poultry manure were applied once in 2 months after small seedlings emerged from soil surfaces. Grow bags 1 and 2, 3, and 4 served as "controls" for non-contaminated growth. Grow bags 7 and 8 were treated with hydrocarbons and poultry manure. In the first generation, coco yams planted in grow bags 7-8 showed growth responses (average values of 1.04 m, 51 cm, 4.45 mg/g for petiole length, leaf blade length, and chlorophyll concentration, respectively) very similar to coco yams planted in pristine soil with poultry manure with average values of 1.00 m, 50 cm, 3.45 mg/g. The cocoyams planted in pristine organic rich soils showed similar response with or without fertilizers (average values of 0.98 m, 48 cm 1.83mg/g and 1.00m, 50 cm, 3.45mg/g) with progressively smaller leaves as generation increases. The cocoyams in hydrocarbon impacted soils generally perform poorer than uncontaminated soil with or without poultry manure by the second and third generation. Poultry manure on soils with re-occurring hydrocarbon contamination exacerbates soil weakening. Mean PAH and mean BTEX concentrations in tubers were 0.001-0.0035 mg/kg and <0.001mg/kg respectively. Cocoyams are not strong BTEX bioactive scavenger but gradually became more concentrated in PAH.

Keywords: BTEX, Cocoyam, Hydrocarbon Pollution, Niger Delta Root Crops, PAH

I. INTRODUCTION

Cocoyam is an edible herbaceous perennial plant belonging to the family Araceae. The two common perennial aroids are the Colocasia esculenta (L.) Schott (Taro) and Xanthosoma mafaffa (Tania) but several others exist.

It is grown in Africa, the tropics and in sub-tropical areas. It is grown mainly for its roof but all parts are edible. It is a security crop as it stores better than other common root crops e.g. yam. Favourable growth condition for cocoyam is a fertile, well-draining, sandy loam soil with a pH from 4.2 to 7.5. Colocasia esculenta has good tolerance of wide variety of wetland conditions. The Nigerian government since the first discovery of petroleum in 1956 in Oloibiri [1] has demonstrated a remarkable determination to increase the proven oil reserve. This has resulted in much growth and opportunities in the petroleum sector [2, 3] [12] [16]. This unfortunately, has also resulted in oil spillage over the year especially in the Niger Delta. Hydrocarbon contamination in the Niger Delta has been well documented in several articles including [4] and the negative adverse effects of hydrocarbon on the soil have been reported by such researchers as [5] and [6]. Most investigation on the effect of hydrocarbon contamination of the Niger Delta involves inoculation of a quantity of soil with hydrocarbon before or after the establishment of the crop [7][13] [14] [15] and [8]. Usually only 1 crop season is considered and the cumulated effect of reoccurring contamination is not considered. This is important especial in root crops. This study is a 3-years documentation of the effect(s) of re-occurring hydrocarbon pollution on cocoyam. Coco yams, in West Africa, are planted from March to May, mature in approximately 8 months and are harvested. The corms are planted in 15-20 cm deep loamy soil in most rural farms. Cocoyam is very important in West Africa, the main nutrient is dietary energy provided by its carbohydrate content with great heath benefit due to its significant vitamin E content and other vitamins (B6 and C) It also contains thiamine, calcium, niacin, manganese, magnesium, copper and riboflavin. It is low in protein content (1-2 %). In studies, cocoyam has been demonstrate to lower blood sugar [9] and reduces bad cholesterol and increase good cholesterol. And can be used by diabetic patients [10].

II. MATERIALS AND METHODS

The investigation studies three generations of cocoyam products to determine the effect of re-occurring hydrocarbon spillage on the root crop. The investigation aims to mimic the experiences of traditional rural farmer and covers 3 generations of cocoyam plant production.

A. Materials

Materials use in this investigation includes:

- Heavy duty fabric canvas
- Clean pristine organic rich soil
- Un-contaminated cocoyams corms
- Spectrophotometer
- chromatography flame ionization detector (GC /FID)
- glass laboratory beaker
- and measuring cylinder

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Heavy duty fabric canvas material was purchased from the market and sewn into several 10-gallons grow bags. The grow bags were labeled “Grow bag 1” to “Grow bag 8”. Each grow bag had a bottom layer of gravel with small-medium size pebbles overlying a fine mesh covering drainage holes. This is to aid removal of any excess water.

Clean pristine organic rich soil was source from the neighbouring rural farmlands. Cocoyam corms were sourced from the local market.

B. Model design

Prior to the placement of the soil inside each grow bag, a representative quantity of the soil was subjected to PAH (Polycyclic Aromatic Hydrocarbon) and BTEX (Benzene, Toluene, Ethyl-benzene, and Xylene) analysis to determine the presence of these chemicals in the soil.

PAH generally have low degree of acute toxicity, non carcinogenic effects, to humans. BTEX are naturally occurring component in crude petroleum and petroleum products such as diesel, gasoline, and aviation fuel. . They are however, deleterious to human health.

Total quantity of soil in each grow bag was approximately 1.37 cubic feet (0.037cublic meter). Each bag was placed outside in a warm sunny location in the university farm and watered using distilled water.

At the start of the investigation (generation 0), “un-contaminated” corms purchased from local market were planted in the pre-prepared grow bags. This represented the zero generation prior to the “spillage” and the parent stock for subsequent generations. As most rural farmers do not purchase new external stock for their farms but would merely select the best from available corms for planting after an oil spillage.

The produced cocoyam, setts and corms from the purchased cocoyam became the zero +1 (0+1) generation which is the first generation.

Corms were planted, 5 days after the grow bags were prepared. The corms were planted at sun rise. Poultry manure was used as organic fertilizers in selected bags (Grow bag 3, Grow bag 4, Grow bag 7, and Grow bag 8) once in 2 months after the small seedlings emerged from the soil surface.

The changes in each grow bag was monitored and documented. Weed, water control were strictly enforced. Watering is dependent on the weather.

On maturity, setts and corms were randomly selected from the harvested produces and stored for next year planting season, which became i +1 generation.

Where:

i = the current generation.

This was also repeated for all subsequent generations.

In each generation, the selected grow bags were subjected to 4 incidences of soil contamination with petroleum to mimic an episode of hydrocarbon spillage. “Grow bag 5” to “Grow bag 8” were treated with a controlled quantity (4 L/cubic meter) of liquid hydrocarbon. Crude oil was introduced to the soil surface in the selected grow bags using a beaker.

The treatments commenced in the month of June each year to the selected grow bags and was replicated twice after 2-3 days interval within the week. The days for the crude oil inoculation in the year 2019 - 2021 are shown in Table 1.

Table I: The days for the crude oil inoculation

Year	Crude Oil Inoculation Dates
2019	June 10,14,17
2020	June 17,21,24
2021	June 19,23,26

The grow bags 1,2.3, and 4 served as “controls” for non-contaminated growth as no liquid hydrocarbon were introduced to these cocoyams.

Furthermore, cocoyams generally have high demand for nitrogen and other minerals [11], thus rural farmers often use organic fertilizer. In this investigation, poultry manure were applied in selected grow bags (grow bags 3, 4, 7, and 8).

At the conclusion of each harvest the following were done:

C. Collection and preparation of samples for laboratory analysis

Samples collected at maturity of the cocoyam plants are leave and roots from the harvest cocoyam plant.

D. Preparation of the collected leaves samples for laboratory analysis

The leaves were washed in distilled water and dried with a clean cotton material prior to weighing and measuring. The prepared leaves were used for chlorophyll extraction.

E. Preparation of the collected roots samples for laboratory analysis

The harvested tubers were washed to remove sand and organic debris. The cocoyam were peeled with a sharp knife and sliced into small cubes for ease of handling and stored in a clean ceramic bowl prior the PAH and BTEX investigations.

F. Chlorophyll extraction

1.0g of leaf sample was weighed and grinded into a paste using a mortar and pestle. Collect paste from mortar using a spatula and place in glass jar. Add 25 ml isopropyl alcohol into the jar and cover. Allow to soak for15minutes. Descant into another glass jar with a filter paper and funnel. A spectrophotometer was used to measure the chlorophyll concentration.

G. PAH and BTEX investigations

Determination of Polycyclic Aromatic Hydrocarbons (PAH) and Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX) were realized by gas chromatography flame ionization detector (GC /FID)

The presence of PAH and BTEX were determined for the soil before the commencement of the investigation and for the roots tubers of the cocoyam for each grow bag for each generation.

i. To determine the presence of PAH and BTEX in the soil

20 g of the organic rich soil was sourced from the neighbouring rural farmlands was treated by removal stones and organic debris and sieved. Prepared soil sample were stored in a nylon bag prior to the GC /FID processing and analysis.

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ii. To determine the presence of PAH and BTEX in the roots

20 g of the prepared root sample was blended into slurry using a laboratory blender. 2 grams of prepared tuber slurry were weighed into two different clean extraction containers.

10 ml of extraction solvent (pentane) was added.

Solution were mixed thoroughly and allowed to settle and filtered into clean solvent extraction bottles using filter paper fitted into Buchner funnels. The extracts were concentrated to 1 ml each and injected into the GC /FID.

H. Storage of selected corms for next planting season

Selected corms were stored from each harvest. These corns were preserved on a raised rack, kept in a dry cool and well ventilated environment for use in the next planting season. This is similar to how traditional rural Farmers preserve and use their farm products from each harvest for the next new generation. The experiment was designed to mimic actions normal carried out by rural Farmers. It analysis a 3-year reoccurring seasonal spillages to capture the effect such an event would have on rustic rural Farmers.

Time line for the cocoyam-pollution project is shown in the appendix. Statistical Analyses was used to identify the variance among groups.

I. Error/uncertainty associated with the method

Rural farmers do not have the luxury to change their farm land after an oil spillage incidence. The action taken by most farmers after a spillage is to allow the farm to "lie fallow" for a period of time before replanting. Thus, the soil used in the grow bags were not changed during the 3 years of the experiment rather the soil was repacked into another grow bag when the bag becomes old with no new soil added. This was an inadequacy in the experiment as a farm land cannot be "repacked" but the Researcher was unwilling to contaminate actual farm land with hydrocarbon.

III. RESULT AND DISCUSSION

Table 2 revealed that the cocoyams planted in hydrocarbon-contaminated soil showed growth responses (petiole length and leaf blade length) similar to cocoyams planted in pristine, unpolluted soils with fertilizer application. The cocoyams planted in pristine organic-rich soils showed similar responses, irrespective of the addition or not of poultry manure as fertilizer in the first year. It was observed that the corns planted in grow bag 1 produced smaller leaves in the third year than in the first and second years. Grow bags 3 and 4 produce much larger leaves. As both grow bags were without contamination, this was interpreted as the effect of the addition of fertilizers in grow bags 3–4, unlike in the first two grow bags. The practice of "shifting cultivation," as practiced by rural traditional farmers, was observed to be beneficial to the land. In shifting cultivation, a piece of land is allowed to lie fallow for a fixed period of time after the crops are harvested. This allows the land to regenerate its fertility naturally.

By the second and third generations, the differences in responses from each grow bag had become more pronounced. With re-occurring contamination, the hydrocarbon-impacted soil shows a progressively weakening response characterized by smaller leaves, less chlorophyll production, and a slight change in PAH concentration in the harvested tubers. The cocoyams planted in hydrocarbon-impacted soils generally perform poorer than uncontaminated soil with and without fertilizers in the second and third years of re-occurring contamination. The use of fertilizers on soils with re-occurring hydrocarbon pollution exacerbates the weakening of the soil.

Table- II: Measure Values from Each Generation

S/N	Grow bag status	Grow bag	petiole length, meter	Leaf blade length, cm	Chlorophyl l, mg/g
Generation-1					
1.	Un-contaminated	1	0.98	48	1.89
2.	Un-contaminated	2	0.98	48	1.76
3.	Un-contaminated + fertilizers	3	1.00	50	3.3
4.	Un-contaminated + fertilizers	4	1.00	50	3.6
5.	Contaminated	5	1.01	52	4.44
6.	Contaminated	6	1.06	**50**	4.46
7.	Contaminated+ fertilizers	7	0.96	46	1.35
8.	Contaminated+ fertilizers	8	0.96	44	1.30
Generation-2					
9.	Un-contaminated	1	0.98	48	1.66
10.	Un-contaminated	2	1.00	48	1.56
11.	Un-contaminated + fertilizers	3	1.00	50	0.96
12.	Un-contaminated + fertilizers	4	1.00	50	0.98
13.	Contaminated	5	0.96	46	3.33
14.	Contaminated	6	0.97	44	2.5
15.	Contaminated+ fertilizers	7	0.95	44	0.94
16.	Contaminated+ fertilizers	8	0.95	44	0.96
Generation-3					
17.	Un-contaminated	1	0.95	47	1.66
18.	Un-contaminated	2	0.99	50	1.66
19.	Un-contaminated + fertilizers	3	0.95	47	4.44
20.	Un-contaminated + fertilizers	4	0.94	44	4.46
21.	Contaminated	5	0.85	43	3.2
22.	Contaminated	6	0.87	43	3.2
23.	Contaminated+ fertilizers	7	0.80	41	0.98
27	Contaminated+ fertilizers	8	0.86	43	0.96

Soil analysis shows a very gradual buildup of PAH with successive generations when routinely contaminated with hydrocarbons (Table 3). The cocoyam tuber, although not a strong bioactive scavenger, gradually became more concentrated in PAH,, but the BTEX concentration is approximately constant (Table 4)

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Table- III: Soil Analysis

Sample	PAH (mg/g)	BTEX (mg/g)
Un-contaminated Soil (start of experiment):	1.00E-06	<0.000001
Un-contaminated Soil (end of experiment):	1.33E-06	<0.000001
Contaminated Soil (start of experiment):	1.00E-06	<0.000001
Contaminated Soil (end of experiment):	3.50E-05	<0.000001

Analysis: uncontaminated soil= 50% uncontaminated with fertilizers + 50% without fertilizers contaminated soil= 50% contaminated with fertilizers + 50% without fertilizers

IV. CONCLUSION

Often, when speaking of pollution air, water and land contamination or pollution comes to mind. Food pollution is often discounted. Although the rate of absorption of Polycyclic Aromatic Hydrocarbons (PAH) and Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX) into the soil is slow the study suggests that the bioactive scavenger constituents of tubers should be monitored to prevent secondary contamination of rural populates living off the land

Table- IV: Tuber PAH BTEX Analysis

		PAH	BTEX
Generation -1; Coco yams harvested			
	Grow bag	mg/g (x 10^{-6})	mg/g (x 10^{-6})
1	Un-contaminated	1.00	< 1.00
2	Un-contaminated	1.00	< 1.00
3	Un-contaminated + Fertilizer	1.00	< 1.00
4	Un-contaminated + Fertilizer	1.00	< 1.00
5	Contaminated	1.05	< 1.00
6	Contaminated	1.05	< 1.00
7	Contaminated+ Fertilizer	1.08	< 1.00
8	Contaminated+ Fertilizer	1.08	< 1.00
Generation -2 ; Coco yams harvested			
1	Un-contaminated	1.00	< 1.00
2	Un-contaminated	1.00	< 1.00
3	Un-contaminated + Fertilizer	1.10	< 1.00
4	Un-contaminated + Fertilizer	1.10	< 1.00
5	Contaminated	1.00	< 1.00
6	Contaminated	2.00	< 1.00
7	Contaminated+ Fertilizer	2.30	< 1.00
8	Contaminated+ Fertilizer	2.30	< 1.00
Generation -3 ; Coco yams harvested			
1	Un-contaminated	1.00	< 1.00
2	Un-contaminated	1.00	< 1.00
3	Un-contaminated + Fertilizer	1.20	< 1.00
4	Un-contaminated + Fertilizer	1.30	< 1.00
5	Contaminated	5.00	< 1.00
6	Contaminated	5.00	< 1.00
7	Contaminated+ Fertilizer	5.10	< 1.00
8	Contaminated+ Fertilizer	5.10	< 1.00

DECLARATION

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Ethical Approval and Consent to Participate	The article does not require ethical approval and consent to participate.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	I am only the sole author of the article.

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APPENDIX

The Gantt chart for the various activities undertaken in the is shown in Table 5

Table- V: Gantt chart for Investigation

	Project	Duration, days	Start date	End date																																		
	Cocoyam investigation	1038	Mar-01-2019	Jan-02-2022																																		
Task ID	**Task**	**Aprox.time, wk**	**Start date**	**End date**	Mar-01-2019	Mar-16-2019	Apr-16-2019	May-17-2019	Jun-17-2019	Jul-18-2019	Aug-18-2019	Sep-18-2019	Oct-19-2019	Nov-19-2019	Dec-20-2019	Feb-18-2020	Mar-20-2020	Apr-20-2020	May-21-2020	Jun-21-2020	Jul-22-2020	Aug-22-2020	Sep-22-2020	Oct-23-2020	Nov-23-2020	Dec-24-2020	Feb-22-2021	Mar-25-2021	Apr-25-2021	May-26-2021	Jun-26-2021	Jul-27-2021	Aug-27-2021	Sep-27-2021	Oct-28-2021	Nov-28-2021	Dec-29-2021	Jan-29-2022
0	Experiment design+logistics	2	Mar-01-2019	Mar-15-2019	x																																	
1	Corms generation - 0 planted	2	Mar-16-2019	Mar-30-2019		x																																
2	PreContamination-	10	Mar-31-2019	Jun-09-2019			x	x																														
3	Oil spillage-Episode 1	1	Jun-10-2019	Jun-17-2019					x																													
4	PostContamination Care of cocyam plant (watering, weeding etc)	18	Jun-18-2019	Oct-22-2019						x	x	x	x																									

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5	Generation -1; Coco yams harvested	4	Oct-23-2019	Nov-20-2019										x																								
6	Generation-1 data analysis	4	Nov-21-2019	Dec-20-2019											x																							
7	Awaiting next planting season	12	Dec-21-2019	Mar-15-2020												x																						
8	Corms generation - 1 planted	2	Mar-16-2020	Mar-30-2020													x																					
9	PreContamination- Care of cocyam plant (watering, weeding etc)	11	Mar-31-2020	Jun-16-2020														x	x																			
10	Oil spillage- Episode 2	1	Jun-17-2020	Jun-24-2020																x																		
11	PostContamination Care of cocyam plant (watering, weeding etc)	18	Jun-25-2020	Oct-29-2020																	x	x	x	x														
12	Generation -2 ; Coco yams harvested	2	Nov-06-2020	Nov-23-2020																					x													
13	Generation-2 data analysis	5	Nov-24-2020	Dec-29-2020																						x												

14	Awaiting next planting season	12	Dec-30-2020	Mar-24-2021																						x												
15	Generation -3; Corms planted	2	Mar-16-2021	Mar-30-2021																							x											
16	PreContamination-Care of cocyam plant (watering, weeding etc)	11	Mar-31-2021	Jun-18-2021																								x	x									
17	Oil spillage-Episode 3	1	Jun-19-2021	Jun-26-2021																										x								
18	PostContamination Care of cocyam plant (watering, weeding etc)	18	Jun-27-2021	Oct-31-2021																											x	x	x	x				
19	Generation -3 ; Coco yams harvested	4	Nov-01-2021	Dec-02-2021																															x			
20	Generation-3 data analysis & Conclusion	4	Dec-02-2021	Jan-02-2022																																x		

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