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Full Length Research

Influence of spent oil on soil physical properties and performance of two okra varieties (*Abelmoschus esculentus*) in PortHarcourt, Rivers State, Nigeria

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ABSTRACT: A study was conducted at the Department of Crop and Soil Science teaching farm, University of Port Harcourt to examine the effect of lubricant automobile oil on soil physical properties and performance of *Abelmoschus esculentus* for a period of eight weeks. Composite soil samples were collected randomly at depths of 0-20 cm. The soil was placed in 10 kg buckets. Spent lubricant oil collected from the automobile mechanic workshop was used to contaminate the soils at 0, 2, 4, and 6% w/v. Two varieties of Okra V1 (local) and V2 (Clensom spineless) were used. Three okra seeds were planted two weeks after contamination and later thinned to two. Each treatment was replicated thrice; the design was completely randomized. The results showed that the spent oil had no effect on per cent germination on V1 in the treatments and at 0 and 2% contamination for V2. As contamination increases, the percent germination of V2 decreases to 83.3 and 72.2% for 4 and 6% respectively. Increase in spent oil contamination reduced the height of the two varieties. V2 was more affected as percent contamination increases in week 1, thereafter, improves better than V1. No significant (p>0.05) difference in number of plant leaves even as contamination increased except in weeks 3, 5 and 6. Number of leaves decreased with increase in level of contamination and increases as the weeks increased in both varieties. Lowest number of leaves observed at 6% and highest at control in the two varieties. Leaf area of both varieties significantly reduced in contaminated over control though varietyV2 was significantly (p<0.05) higher than V1. Contamination of the soil did not change the textural class of the soil. Significant decrease was recorded in hydraulic conductivity of the soil between the contaminated and control. As the contamination level increased, hydraulic conductivity decreased. Contamination of the soil with lubricant oil increased the soil bulk density. The effect of hydrocarbon contamination was pronounced as there was delay in plant germinations, poor and stunted growth of the two varieties, and yellowing of leaves at the seventh and eighth weeks, especially at 6% contamination on both varieties.

Keywords: Okra performance, spent oil contamination, soil physical properties.

INTRODUCTION

Spent oils are obtained from internal combustion engines of automobiles and machines resulting from lubricant oils which are used over some time. It is obtained after draining the engine oil sump during servicing and lubricating oil from the engines of vehicles when the oil is changed (Iren and Ediene, 2017; Stephen *et al*., 2013). Improper disposal and management of this waste constitute a major problem for the environment.

Spent oil pollutes the environment when it is improperly managed and disposed into ponds, land sewage and surface carnages through automobile crank cases, oil seal leakages, and application on rural roads for dust control, mitigation, and over land flow during precipitation (ATSDR, 1997; Uchendu and Ogwo, 2014; Odjegba and Sidig, 2002). Disposal of lubricating oil in the gutter, water drain, vacant plots and farmland is a common practice in developing countries, especially in Nigeria (Okonokhua *et al.*, 2007).

Spent oil contains high levels of hydrocarbon, heavy metals and polycyclic hydrocarbon which are very toxic, amines, phenol, benzene chlorinated biphenyls (Whisman *et al*., 1974; Wang *et al*., 2000; Umunnakwe *et al*., 2020). Hydrocarbon has been reported to be responsible for reduced soil quality and crop yield (Adeoye *et al*., 2005).

The chemical reaction inside of metals in the car engine over time causes wear and tear into the engine oil causing impurities of the oil to high and causing the oxidation of hydrocarbon chains to form sludge. Incombustible gasoline, about 5% weight, usually leaks from the fuel injector line into the engine oil causing contamination (Nwachukwu *et al*., 2020). Engine oil is discarded as spent oil when there is no addictive function in it again (Ogbeide, 2010). The dark colouration is a result of carbon from wear.

Spent oil is formed as a result of changes in viscosity, addictive depletion and oxidation (Ayandele, 2018). It causes the degradation of soil (Censi *et al*., 2006). When the environment is polluted, it affects the soil and its productivity, reduction in soil quality thus reducing the abundance and diversity of micro-organisms (Abosede, 2013; Censi *et al*., 2006, Blott and Pye, 2012). When the environment is polluted with spent oil, it affects the soil and its productivity (Abosede, 2013).

Studies have shown that spent engine oil contamination on agricultural soil reduced soil capillarity, porosity and water holding capacity of soils while the soil bulk density increases as the level of contamination increases (Kayode *et al*., 2009; Udonne and Onwuma, 2013; Uchendu and Ogwo, 2014; Iren and Ediene, 2017).

When spent oil is discarded into the soil, it is absorbed into the soil particles, reducing its porosity and aeration (Warmate *et al.,* 2011). Soil contamination with spent oil remains unsuitable for planting for months or years until degraded to a tolerable level (Anoliefo *et al.,* 2001). The presence of spent oil and heavy metals pose risks to plants, animal and human health (Mishra et al., 2015), There is also yield reduction, impaired fecundity, chlorosis, necrosis, bleaching, spotting of leaves and malformation of epidermal cells, the roots stress, growth retardation and dehydration as a result of water stress (Salami and Elum, 2010; Quiñones-Aguilar *et al.,* 2003), lower germination count and delay seed germination have also been reported (Ekundayo *et al*., 2001; Adenipekun *et al.,* 2008).

Okra *(Abelmoschus esculentus)* is a common staple vegetable in Africa, especially Nigeria. The need to investigate factors that hinder its proper growth and performance becomes necessary. The study, therefore, is aimed at examining the effects of spent oil on (i) some soil physical properties and (ii) growth and performance of two varieties of okra plants.

MATERIALSANDMETHODS

Experimental Site

The study was conducted at the Department of Crop and Soil Science Research Farm, Faculty of Agriculture, University of Port Harcourt, Nigeria. The site is located at latitude 4° 54' 29'' N and longitude 6° 54' 58'' E of the equator with an elevation of 16 m above sea level. The mean annual monthly rainfall is 200.45 mm (Uko and Tamunobereton-Ari, 2013) and is bimodal in nature with the peak in June and September. The rainy season starts from April to October while the dry season period is from November to March. The average maximum monthly temperature is 31.29°C and the minimum is 21.80°C (Uko and Tamunobereton-Ari, 2013). The relative humidity varies between 35 to 90% depending on the particular period of the year.

Collection of soil and spent oil samples

Random composite soil samples were collected from the Department of Crop and Soil Science Research Farm depth of 0-20 cm. Ten (10) kilograms of soil were placed in 24 medium sized perforated plastic pots. Spent oil (from the same source to ensure the same quality) was collected from the roadside automobile motor mechanics workshop. The spent oil was used to contaminate each of the pots at the rate of 0, 2, 4 and 6% representing 0, 200, 400 and 600 mls w/v basis per pot respectively. The spent oil was evenly worked into the soil.

Collection and planting of okra (*Abelmoscus esculentus*)

Okra seeds of two different varieties V35 – local variety (V1) and V119 – Clemson spineless variety (V2) were collected from Rivers State Agricultural Development Project (ADP) farm Rumuodomaya, Port Harcourt. Three seeds each of these varieties were planted in each of the plastic pots two weeks after contamination. The pots were left on the field. The experiments were done during the dry season. The pots were watered with 200 ml of water from a watering can three times a week.

Hand picking of weeds was done when the need arises while the seedlings were thinned to two four days after germination. The experiment was left for a period of 56 (8 weeks). The design was a 2 × 4 completely randomized design (CRD), replicated thrice bringing it to a total of twenty four (24) pots.

Plant data collection

Germination percentage was taken one week after planting in all the pots starting from three days after planting. Plant height was measured at seven days intervals after germination for a period of eight weeks using a meter rule. Measurement was from the soil surface to the point of leaf convergence and the average mean height was recorded for each pot. The number of each leaf (leaf tiller) on each plant stand was counted physically, and the average was taken. The leaf area was taken with the meter rule and calculated using 0.62 × leaf length × leaf width according to (Musa and Usman, 2016).

Collection of soil samples for laboratory analysis

Composite soil samples were collected from each of the pots with a hand trowel. They were crushed with hands and left to air dry at a room temperature of 23-25°C in the laboratory. The dried samples were pulverized with mortar and pestle, sieved in a 2 mm mesh screen and stored in polythene bags awaiting laboratory analysis.

Analysis of soil physical properties and total hydrocarbon content

The soil physical properties analyzed include particle size analysis using the Hydrometer method as reported by Gee and Or (2002). Hydraulic conductivity was determined using the Constant Head method as reported by Reynolds *et al*. (2002) while the bulk density was estimated by dividing the oven-dry mass of the soil by the volume using Grossman and Reinsch (2002) method. The total hydroc content was carried out using the standard laboratory method as reported by Odu *et al*. (1985).

Statistical analysis

The collated data were subjected to analysis of variance (ANOVA) to determine the difference between the mean of variance at 0.05 level of significance. The difference between the treatments was assessed from the least significant difference (LSD) post hoc test.

RESULTS AND DISCUSSION

Germination percentage

The results of the study on seed germination are presented in Table 1 below. The result showed no significant ($p>0.05$) difference between the two varieties of okra in the control plot and at a 2% level of contamination. As the level of contamination increases from 4 to 6%, significant ($p<0.05$) differences were observed between the two varieties of okra (V1 and V2).

Variety V1 (local variety) had 100% germination within seven days after planting in all the treatments, implying that an increase in the level of treatments had no effect on the per cent germination of the local variety V35 (V1). Variety V2 (V119-Clemson spineless) had 100% germination at 0 and 2% treatment levels, as the level of treatment (contamination) increases to 4 and 6%; germination percentage decreases to 66.7 and 44.4%, respectively indicating that increase in spent oil contamination negatively affected the per cent germination and survival of V119-Clemson spineless variety (V2).

This agrees with the reports of Oyedeji *et al*. (2012), Uquetan *et al*. (2017), Adenipekun *et al*. (2008) and Ekundayo *et al*. (2001) who reported a decrease in germination in spent oil polluted soil. There was a delay in germination in most of the okra seeds, especially in V119-Clemson spineless (V2) within the first five days of planting at 4 and 6% levels of contamination. The final germination was observed on the 7th day after planting. This is in line with the finding of Okonokhua *et al*. (2007) who reported a delay in maize germination in spent oil contaminated soil.

Plant height

Results in Table 2 showed the plant height of okra in the study. There was no significant ($p>0.05$) difference in control samples between the local variety- V35 (V1) and V119-clemson spineless (V2) in all the weeks of the study with the exception of day 7 ($5.5±1.05^a$ and $1.9±0.10^c$), 28 ($17.2±3.01^a$ and $15.1±0.76^b$) and 49 ($32.2±1.89^a$ and $34.2±1.15^b$) for V1 and V2 respectively, while significant ($p<0.05$) difference was observed between the contaminated and control samples in all the days in the two varieties (V1and V2) studied.

The results, therefore, showed that contamination of the soil with spent oil negatively affected the height of the two varieties (V1 and V2) of okra. As the level of spent oil contamination increases, a significant ($p<0.05$) reduction was observed in the height of the two varieties of okra investigated. These observations agree with the findings of Agbogidi *et al*. (2007), Njoku *et al*. (2012) and Uquetan *et al*. (2017) who in their different studies reported retarded growth and adverse effects on the plant height as the level of spent oil contamination increases.

Variety V2 (V119-clemson spineless) appears to be more affected by an increase in the level of spent oil contamination in the first seven days of the experiment ($1.6±0.10^c$ against V1 with $3.6±0.0^b$ at 2% contamination, $1.1±0.12^c$ against V1 with $3.6±0.06^b$ at 4% and $1.0±0.06^c$ against V1 with $3.0±0.9^b$ at 6% level of contamination), thereafter, V2 improves in height than the local variety-V119 (V1) as the number of weeks increases even better than the local variety. The height of the two-okra variety was significantly affected at a 6% level of spent oil contamination though the effect was more on the improved variety than the local.

Effects of spent oil on number of leaves

Table 3 showed the results of the number of leaves of both varieties of okra planted. It revealed that there was no

Table 1. Germination percentage of okra varieties seven days after planting.

Contamination %	Okra variety 1 (V1)	Okra variety 2 (V2)	Average
0	100.00	100.00	100.00
2	100.00	100.00	100.00
4	100.00	66.66	83.33
6	100.00	44.44	72.22

V1 is the local okra variety and V2 is Clemson spineless variety.

Table 2. Mean plant height at seven days intervals.

Cont. %	Okra variety	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56
0	V1	5.5±1.05[a]	10.3±0.28[a]	13.4±1.27[a]	17.2±3.01[a]	21.4±2.48[a]	22.7±2.27[a]	32.2±1.89[a]	32.9±1.31[a]
	V2	1.9±0.10[c]	9.9±0.53[a]	13.1±1.50[a]	15.1±0.76[b]	20.1±1.25[a]	20.9±2.28[a]	34.2±1.15[b]	33.5±0.00[a]
2	V1	3.6±00[b]	6.7±0.76[b]	7.0±0.84[c]	6.9±0.12[d]	7.07±0.05[d]	7.3±1.04[d]	7.8±0.64[e]	8.20±0.61[e]
	V2	1.6±0.10[c]	7.5±1.00[b]	10.2±1.72[b]	11.0±1.00[c]	12.7±0.29[b]	11.8±0.64[b]	15.9±1.01[c]	16.1±1.02[b]
4	V1	3.6±0.06[b]	6.1±0.11[c]	6.1±0.003[c]	6.20±0.27[d]	6.2±0.25[d]	6.4±0.36[d]	7.1±0.51[e]	7.3±0.42[e]
	V2	1.1±0.12[c]	6.4±0.12[c]	10.4±0.45[b]	11.3±1.16[c]	11.3±0.29[b]	11.5±0.28[bc]	14.5±1.00[c]	14.7±0.98[b]
6	V1	3.0±0.91[b]	5.9±0.16[c]	6.2±0.15[c]	6.3±0.29[d]	6.3±0.29[d]	6.8±0.25[d]	6.8±0.35[e]	6.9±0.36[e]
	V2	1.0±0.06[c]	6.7±0.40[b]	7.8±0.61[c]	8.0±0.62[d]	9.0±1.00[c]	9.8±0.50[c]	11.2±1.04[d]	11.2±1.12[d]

Values with the same superscripts on the same column are not significantly different. V1 = local okra variety and V2 = Clemson spineless variety, and Cont. = contamination.

Table 3. Mean plant number of leaves at seven days intervals.

Cont. %	Okra variety	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56
0	V1	7.7±1.53[a]	12.0±0.00[a]	14.7±1.53[a]	17.0±1.00[a]	18.7±1.15[a]	15.7±2.31[a]	17.0±1.73[a]	17.0±1.73[a]
	V2	6.0±0.00[ab]	10.0±1.00[ab]	13.0±1.73[ab]	16.3±1.15[a]	14.7±0.58[ab]	14.3±1.15[a]	13.7±0.58[b]	13.7±0.58[b]
2	V1	3.0±0.00[c]	8.3±1.15[bc]	7.0±3.46[c]	6.7±0.58[b]	5.7±0.58[c]	4.3±0.57[c]	4.3±0.58[c]	4.3±0.58[c]
	V2	4.3±2.08[bc]	8.3±1.15[bc]	10.0±1.00[b]	6.7±1.15[b]	7.7±0.58[b]	6.3±1.15[bc]	4.7±1.53[c]	4.7±1.53[c]
4	V1	2.7±0.58[c]	7.3±2.89[c]	8.0±2.65[bc]	5.7±1.53[bc]	5.0±1.00[d]	6.7±1.15[bc]	5.7±0.57[bc]	5.7±0.57[bc]
	V2	4.0±0.00[bc]	6.0±0.00[cd]	5.7±0.57[cd]	3.7±0.58[c]	5.7±2.08[c]	5.3±1.15[c]	5.0±1.00[c]	5.0±1.00[c]
6	V1	3.0±0.00[c]	6.3±0.57[c]	7.3±0.57[c]	5.0±1.73[bc]	5.3±1.15[d]	5.7±0.58[bc]	5.7±0.57[bc]	5.7±0.57[bc]
	V2	2.7±1.15[c]	5.6±0.57[cd]	6.0±1.00[cd]	4.7±1.15[bc]	5.3±1.52[d]	4.3±0.58[c]	4.0±0.00[c]	4.0±0.00[c]

Values with the same superscripts on the same column are not significantly different, + V1 = = local okra variety, V2 = Clemson spineless variety, and Cont. = Contamination.

significant ($p>0.05$) difference in plant number of leave in the control from day 28 (17.0±1.00[a] and 16.3±1.15[a]) for V1 and V2 respectively, day 42 (15.7±2.31[a] and 14.3±1.15[a]) for V1 and V2 respectively, however, a significant difference was observed at day 49 (17.0±1.73[a] and 13.7±0.58[b]) for V1 and V2 respectively and for day 56 (17.0±1.73[a] and 13.7±0.56[b]) for V1 and V2 respectively. There was a significant ($p<0.05$) difference between the number of leaves on the control and the different levels of treatments. There was no significant ($p>0.05$) difference observed between 4 and 6% levels of contamination for both varieties of okra for most of the weeks except days 21, 35 and 42. This result showed that as the level of contaminant increased, the number of plant leaves was not significantly ($p>0.05$) different from other levels of contamination, however significant ($p<0.05$) difference was observed from that of the control from day 7 to day 56 for both varieties and at higher (4% and 6%) levels of contaminations at weeks 3 (21), 5 (35) and 6 (42) days.

The number of leaves decreased with an increase in the levels of contamination and increased as the week increased in both varieties. The number of leaves measured for the control throughout the eight weeks was significantly different for both okra varieties. There were significant differences between the two okra varieties for 0% contamination for the 1st, 2nd, 3rd, 5th, 7th and 8th

Table 4. Mean plant leaf area at seven days intervals.

Cont. %	Okra Variety	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56
0	V1	3.9±0.21[a]	7.8±1.55[a]	12.7±1.33[b]	32.6±5.67[a]	56.1±4.85[a]	62.9±5.08[a]	66.7±4.62[a]	68.7±3.72[a]
	V2	3.1±0.05[b]	4.5±1.58[b]	23.9±3.39[a]	23.9±3.39[b]	38.9±5.59[b]	41.7±5.67[b]	67.0±28.6[a]	50.4±1.44[b]
2	V1	1.6±0.55[c]	1.6±0.27[c]	1.64±0.29[cd]	1.7±0.36[c]	1.8±0.42[d]	2.0±0.06[d]	2.8±1.04[c]	3.0±1.03[c]
	V2	1.81±0.18[c]	2.3±0.51[c]	3.79±0.29[c]	3.8±0.29[c]	3.5±0.44[c]	4.0±0.38[cd]	4.6±0.09[b]	4.8±0.10[c]
4	V1	0.9±0.23[d]	0.9±0.12[d]	0.97±0.15[d]	1.1±0.12[d]	1.4±0.08[d]	1.6±0.05[d]	1.7±0.14[c]	2.3±0.45[d]
	V2	2.0±0.07[c]	1.9±0.30[c]	3.14±0.56[cd]	3.14±0.56[c]	3.0±0.45[c]	3.7±0.36[cd]	5.5±1.00[b]	5.0±0.52[c]
6	V1	0.9±0.14[d]	0.9±0.11[d]	0.95±0.14[d]	1.0±0.11[d]	1.1±0.09[d]	1.3±0.13[d]	1.3±0.15[b]	1.5±0.09[d]
	V2	0.6±0.03[d]	1.3±0.10[c]	1.9±0.16[cd]	1.9±0.15[c]	2.9±0.64[c]	10.7±0.49[c]	4.8±0.41[b]	4.7±0.32[c]

Values with the same superscripts on the same column are not significantly different, + V1 = Local okra variety, V2 = Clemson spineless variety, and Cont. = contamination.

Table 5. Some physical properties of the spent oil contaminated soil.

Contamination %	Sand (%)	Silt (%)	Clay (%)	HC (cm/hr)	BD (g/cm^3)	TTC
0	84.60±0.00[a]	5.09±1.54[c]	10.31±1.54[b]	3.00±0.14[a]	1.24±0.02[c]	LS
2	78.6±5.65[c]	12.24±5.74[a]	9.16±0.08[c]	2.62±0.19[ab]	1.43±0.02[b]	LS
4	82.4±5.65[ab]	6.42±5.74[cb]	11.05±0.08[a]	2.16±0.35[b]	1.44±0.00[b]	LS
6	81.6±1.41[b]	8.35±1.54[b]	9.01±0.13[c]	1.91±0.00[c]	1.48±0.00[a]	LS

Values with the same superscripts on the same column are not significantly different, NS show no significant difference. LS: represent loamy sand.

week. However, the performances of the two varieties are not significantly different for the fourth and sixth weeks on 0% contamination levels. Okra variety V2 had a lesser number of leaves than variety V1 for most of the contamination levels. The lowest number of leaves was observed from the 6% levels of contamination while the highest number of leaves was observed at 0% contamination level.

Effect on leaf area of okra varieties

The results of the leaf area of the two okra varieties (V1 and V2) are as presented in Table 4. A significant ($p<0.05$) difference was observed between the local variety (V1) and variety V2 (V119-clemson spineless) in control samples. The local variety significantly increased over variety V2 (V119-clemson spineless). The leaf area of both varieties was significantly ($p<0.05$) reduced in spent oil contaminated soil over control.

There was a significant difference in the plant leaf area between the two varieties in contaminated samples. A significant difference was observed at 4% (0.97±0.15[d] and 3.14±0.56[cd], 1.4±0.08[d] and 3.0±0.45[c], 1.7±0.14[c] and 5,5±1.00[b] and 2.3±0.45[d] and 5.0±0.52[c]) for V1 and V2 respectively and at 6% (0.95±0.14[d] and 1.9±0.16[cd], 1.1±0.09[d] and 2.9±0.64[c], 1.3±0.15c and 4.8±0.41[b] and 1.5±0.09[d] and 4.7±0.32[c]) level of contamination between V119-clemson spineless (V2) and local variety (V1) in weeks 3, 5, 7 and 8. The results, therefore, revealed that the leaf area of variety V2 was significantly higher than the local variety.

This report is in tandem with the findings of Agbogidi *et al*. (2007) and Okonokhua *et al*. (2007) who reported a significant difference in plant leaf area as the level of contamination in soil increases. The report also corroborates with the study of Okonokhua *et al*. (2007) who inferred in their investigation on the effects of spent oil on soil properties and growth of maize plants revealed that the level of spent oil contamination adversely affected the plant leaf area, root size, root length and plant height.

Effect on soil physical properties

The results of the study on soil physical properties (Particle size, hydraulic conductivity and bulk density) of the soil are presented in Table 5. The soil particle size percentage ranges from 84.60±0.01[a] in control to 78.60±1.41[c] in spent oil contaminated soil for sand, 12.24±7.72[a] in contaminated to 5.09±1.54[c] in control silt and 10.31±1.51[a] in control to 8.98±0.08[c] in contaminated for per cent clay. The results revealed a significant ($p<0.05$) difference between the control and spent oil contaminated samples in all the particle size distributions. Percentage (sand and clay) was significantly higher in control than contaminated with exception of silt. The textural class of the studied soil is loamy sand. The result, therefore, showed that contamination of the soil did not change the textural class of the soil. This finding is similar to the report of Okonokhua *et al*. (2007) and Abosede (2013).

Hydraulic conductivity

The soil hydraulic conductivity increased from 1.91±0.01[c] in contaminated to 3.00±0.14[a] in control samples. This showed a significant ($p<0.05$) decrease in hydraulic conductivity in spent oil contaminated soil over control. As the level of contamination increases (6%), the soil hydraulic conductivity decreases. This observation tallies with the report of Agbogidi and Enujike (2012) and Ogboghodo *et al*. (2005) who in their studies noted that soil contaminated with spent oil reduces the soil hydraulic conductivity. Nwite and Alu (2015) in their study corroborated the report as they reported a decrease in hydraulic conductivity as the level of spent oil contamination increased.

Bulk density

The bulk density of the soil decreases from 1.24±0.02[c] in control to 1.48±0.01[a] in soil contaminated with spent oil. The significant ($p<0.05$) increase in contaminated (1.43£0.02[b] at 2%, 1.45£0.00[ab] at 4% and 1.48£0.00[a] at 6%) over control (1.42±0.02[c]) samples is an indication that spent oil contamination increases the bulk density of soil. The increase in bulk density could be possibly be attributed to soil compaction which may have being caused by the spent oil which may have blocked the pore spaces thereby reducing the soil total porosity. This observation was affirmed by the findings of Mba *et al*. (2010), Nwite *et al*. (2020) and Nwite and Alu (2015). However, Abosede (2013) reported a contradictory finding that bulk density reduced with the level of contamination.

The spent oil which may have blocked the soil pore spaces thus displacing water and air from entering the soil could possibly be responsible for the reduced soil porosity. This agrees with the work of Nwite *et al*. (2020), Nwite and Alu (2015), Mbah *et a*l. (2010) and Iren and Ediene (2017). The bulk density of the soil increases with increase in spent oil contamination.

Total hydrocarbon content (THC)

The result of the soil THC is presented in Table 5. The THC ranges from 8.92±2.18[d] in control to 627.4±0.13[c] for 2%, 038.18±0.20[b] for 4% and 1423±0.01[a] for 6% levels of contamination. The result revealed a significant increase in soil contaminated with spent lubricant oil over control. This finding tallies with the studies of Chukwumati and Abam (2021) and Devatha *et al*. (2019) who reported an increase in THC in crude oil contaminated soil over control. The total hydrocarbon content increases in the soil with an increase in the level of spent oil lubricant contamination.

The effect of this was very pronounced in the plant (Okra) as there was delayed germination, poor growth and performance of the two varieties of okra, stunted growth, chlorosis within the eight (8) weeks of study. The highest concentration of THC was recorded on a 6% level of contamination. The negative effect on the two varieties of okra plants was very significant as recorded on the plant growth indicators.

Conclusion and Recommendation

The results from the study showed that spent lubricating oil negatively impacted the soil's physical properties investigated and the general performance of the plant - okra (*Abelmoschus esculentus*). This is shown by delayed germination, stunted growth of the plant, yellowing of leaves, dropping of tender leaves and poor root development, especially at higher levels of contamination. Furthermore, indiscriminate discarding of used lubricant oil should be avoided especially in areas that are used for plant cultivation.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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