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Effect of Spent Engine Oil on the Soil Properties and Growth Parameters of Green Amaranth (*Amaranthus viridis* Linnaeus) in a Laboratory Condition in Lagos State, Nigeria

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ABSTRACT: Increased discharge of spent engine oil in the environment due to increased use of automobiles and other engines and their subsequent maintenance is a matter of great environmental concern. This study assessed the effect of spent engine oil on soil properties and the growth performance of *Amaranthus viridis* in a laboratory setting in Lagos State Nigeria using standard methods. Viable *Amaranthus viridis* seeds were sown in soil contained in five plastic containers treated with 100ml, 75ml, 50ml, 25ml and 0ml (as control) of spent engine oil, separately. Each treatment had three replicates. Measurements of the plant's leaves, leaf area and height of shoot were taken at a 7-day interval up to sixty-three days. The physicochemical parameters of the spent engine oil-polluted soil were also analyzed at the beginning and at the end of the experiment. Data generated from this study were analyzed using SPSS, separating mean differences at 5% level of significance ($p < 0.05$). The levels of nitrogen and potassium were lower in the contaminated soil than the control while the levels of phosphorus were higher in the spent engine oil-contaminated soil. Sodium, calcium, iron and lead concentrations in soil increased with increasing amounts of spent engine oil. The spent engine oil had an effect on the pH and the total organic carbon. In comparison to the control, *Amaranthus viridis* grown in the polluted soil had adverse effects on the number of leaves, plant height, and leaf area. These results showed that spent engine oil affects both the quality of the soil and the growth parameters of the plant (*Amaranthus viridis*) which can be used to inform farmers and agriculturalists how adverse the effect of spent engine oil is to our plants and ecosystem.

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Spent engine oil, often found in automotive or mechanical workshops, is the result of servicing car and generator engines and draining them afterwards. This oil can also originate from industries in the form of hydraulic oil, turbine oils, process oil, and metal working fluids (Lale *et al.*, 2014). Moreover, spent engine oil can come from ocean-going vessels, containing saltwater, heavy and intermediate fuel oil, and various heavy metals commonly found in such fuel oil (Olugboji and Ogunwole, 2008). Toxic components of spent engine oil include numerous organic chemicals and heavy metals accumulated from the lubricated engine (Helmenstine, 2013; Lale *et al.*, 2014). These organic chemical constituents consist of low and high-molecular-weight aliphatic hydrocarbons, aromatic hydrocarbons, polychlorinated biphenyls, lubricative additives, chlor dibenzofurans, and decomposition products (Helmenstine, 2013). Heavy metals in spent engine oil include aluminium (Al), chromium (Cr), tin (Sn), lead (Pb), manganese (Mn), nickel (Ni), and silicon (Si) (Njoku *et al.*, 2012). Careless disposal of spent engine oil contributes significantly to environmental pollution (Onwusiri *et al.*, 2017). Contamination of open spaces, farms, gutters, and water drains by spent engine oil poses serious monitoring and control challenges, as it easily leaches into the environment, polluting water and soil (Olugboji and Ogunwole, 2008; Onwusiri *et al.*, 2017). Soils contaminated by spent engine oil are a matter of environmental concern as they have the potential to contaminate surface and groundwater, making them unsuitable for various purposes (Iqbal *et al.*, 2016). Spent oil-contaminated soil is not suitable for agriculture due to nutrient depletion or toxicity (Ikhajiagbe *et al.*, 2013). Soil contamination by spent engine oil also results in increased levels of heavy metals, such as chromium, tin, lead and manganese, beyond plant thresholds (Ugwu *et al.*, 2019). High concentrations of these metals negatively impact seed germination, reduce crop yield, and can cause premature plant death (Ikhajiagbe *et al.*, 2013). Excessive manganese in spent oil-contaminated soil can cause metabolic disorders and growth inhibition in many plant species (Ikhajiagbe *et al.*, 2013).

Amaranthus viridis, also known as slender or green amaranth, local tote, and African spinach, is an annual, highly branched plant with edible ovate, long leaves and stems that can grow up to 60-80 cm (Reyad-ul-Ferdous *et al.*, 2015; Akbar *et al.*, 2017). *A. viridis* belongs to the Amaranthaceae family and Amaranthus genus (Tongos, 2016). It has a cosmopolitan distribution, particularly in warm regions worldwide (Akbar *et al.*, 2017; Ogwu, 2020). *A. viridis* is widely cultivated in tropical, subtropical, and warm temperate regions (Ogwu, 2020). In Nigeria, it is a common food and vegetable source for many farmers. Among weedy amaranths, *A. viridis* is the most consumed (Tony-Odigie *et al.*, 2012). It also has therapeutic potential against various ailments, such as diabetes, cancer, ageing, arteriosclerosis, dysentery, and eye infections (Akbar *et al.*, 2017). Additionally, it has economic value in soap making, forage, green manure, and silage (Alegbejo, 2013; Akbar *et al.*, 2017). *Amaranthus viridis* is highly susceptible to the toxic effects of oil-contaminated soil (Ramanlal *et al.*, 2020). Its sensitivity can vary based on specific environmental and human factors, making it crucial to consider these factors when growing or managing the plant (Roychowdhury *et al.*, 2020).

Past research has shown that exposure to spent engine oil can cause changes in soil pH, texture, and nutrient content, leading to reduced soil fertility and plant growth (Okonokhua *et al.*, 2016; Adekunle *et al.*, 2019). However, there is still limited understanding of the extent and duration of these effects, as well as the mechanisms by which spent engine oil interacts with soil and plant systems. Therefore, this study was aimed to investigate the effects of spent engine oil on soil properties and the growth of *Amaranthus viridis* in a Laboratory setting in Lagos State, Nigeria.

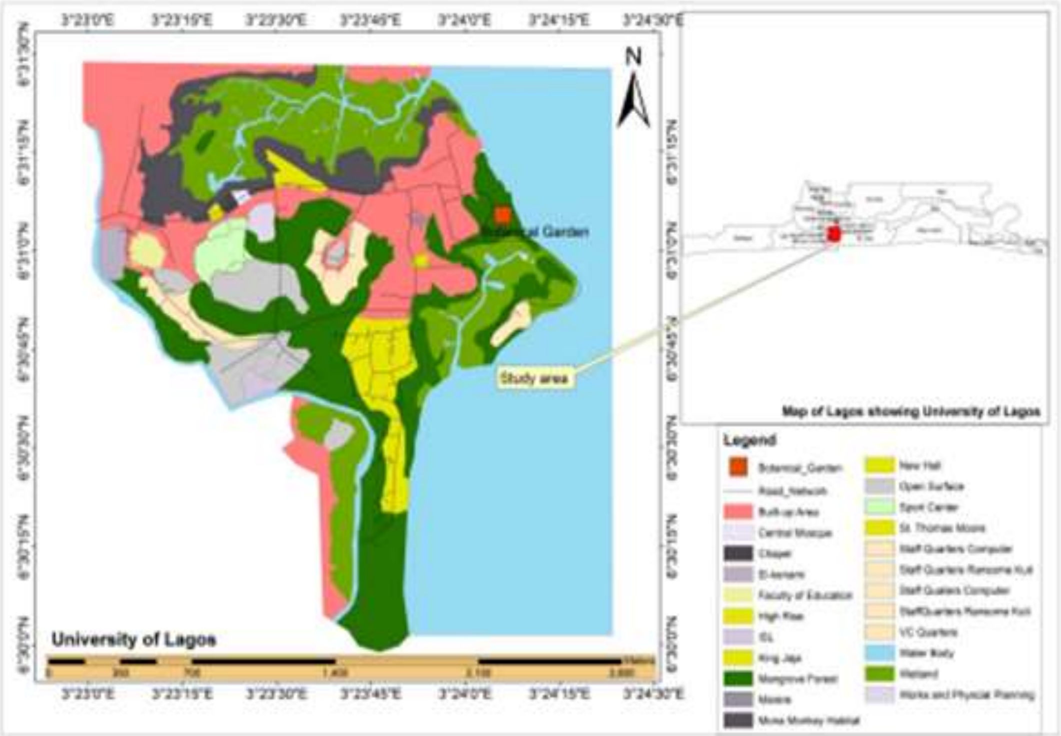

Fig 1: University of Lagos showing the study area.

MATERIALS AND METHODS

Study Location: This study was conducted in the Cell Biology and Genetics lab at the University of Lagos, Akoka, Yaba, Lagos state, Nigeria (Figure 1). The University is situated in the North- East of Lagos, in the Lagos Mainland Local Government Area of Lagos State Nigeria. It lies along the latitude 6º 30’N and longitude 3 º24’E (Nodza *et al.,* 2014). The University of Lagos is situated in an area encompassing various types of vegetation, including freshwater swamp, mangrove swamp, sandy plain vegetation, and upland vegetation, while being bordered to the south by Lagos Lagoon, adjacent to the Atlantic Ocean, covering approximately 802 acres (3.25 km^2) of land (Oni and Ndiribe, 2019; Nodza *et al.*, 2021).

Source of Materials: Amaranthus viridis seeds were procured from Oyingbo market in Lagos state, while spent engine oil was obtained from petrol engines in mechanic workshops located in Sabo, Yaba, Lagos State. The University of Lagos' botanical garden supplied the soil samples for planting.

Experimental Design: The experimental design used two soil types, sandy and loamy, which were sieved and mixed before being placed in experimental containers at a weight of 4 kg per container (Olayinka and Arinde, 2012). Varying volumes of spent engine oil, (100 ml, 75 ml, 50 ml, 25 ml and 0 ml as a control group), were added as treatments, and viable *A. viridis* seeds were planted in both the treated soils and the control group (Obazuaye and Obueh, 2014).

Determination of Soil Nutrient Content: The phosphorus content of the soil samples was determined using the molybdenum blue spectrophotometric method at 880 nm, following the procedure described by Terry *et al.* (2000) and Herndon *et al.* (2020). Ten millimetres of the filtrate was mixed with HACH PhosVer 3 phosphate reagent, and the resulting solution was analyzed for phosphorus content using a spectrophotometer. The phosphorus content of the soil was calculated using the formula:

$$P\ (mg/kg) = \frac{C_P E\ x\ V_F}{W_S}$$

Where: P = phosphorous (m/kg) in soil sample; C_PE = concentration of phosphorous in extract; V_F = Final Volume; W_S = weight of sample

The nitrogen content of the soil was determined using a colourimetric method described by Ahmed *et al.* (2020), which involved the extraction of nitrate using a calcium sulfate solution. After clarifying the extract, 10 ml of the pretreated sample filtrate was mixed with HACHNitraVer 5 Nitrate reagent powder pillow, and the resulting solution was allowed to develop colour. The colour intensity was then compared using a colour comparator box, and the corresponding value on the scale window was recorded. The average value was multiplied by 2 to obtain the available nitrate-nitrogen in the soil. Method validation was performed using a nitrogen standard solution and matrix spike.

Determination of Soil Heavy Metal Content: The standard flame atomic absorption method as described by Aluko *et al.* (2018) was used to determine the sodium, magnesium, potassium, calcium, and zinc contents in soil samples. The soil samples were air-dried, ground, and passed through a 100-mesh sieve. Then, 5.0 mg of each sample was weighed and mixed with 50 ml of acidified ammonium oxalate solution. After evaporation and heating, the sample was dissolved in hydrochloric acid and digested. A Perkin Elmer Model Analyst 300 AAS with a fuel-rich flame and hollow cathode lamp was used to determine the mineral contents (Aluko *et al.*, 2018).

The absorbance of the sample was measured at the corresponding wavelengths for each element. The concentrations of sodium, magnesium, potassium, calcium, and zinc were calculated using the formula:

$$C_M\ (mg/kg) = \frac{C_{STD}}{ABS_{STD}}\ x\ \frac{C_{ABS}}{SW_{sample\ eight}}\ x\ 1000$$

Where C_M = concentrations of the metal ions; C_{STD} = concentration of the standard of the metal; ABS_{STD} = Absorbance of the standard; C_{ABS} = Absorbance of the sample; $SW_{\text{weight of the sample}}$ = Weight of the sample

Standard concentration (Na: 0.5mg/L; Mg: 0.3mg/L; K: 2.0mg/L; Ca: 4.0mg/L; Zn: 1.0mg/L; Fe: 5.0mg/L).

Determination of Soil Physicochemical Parameters: The soil samples' physicochemical properties were analyzed before sowing *Amaranthus viridis* and after the nine-week growth of the plant. Soil pH was determined using a soil solution slurry method with a pH meter (Buurman *et al.*, 1996). Organic carbon was measured using the standard Dichromate Method, and organic matter was calculated as a percentage of organic carbon (Sahito *et al.,* 2017). The percentage change in physicochemical parameters was determined with the following formula (Azlan *et al.*, 2012):

$$\%\Delta\ \text{PP} = \frac{P_{FV} - P_{IV}}{P_{IV}}\ x\ 100$$

Where = %ΔPP = percentage change of physicochemical parameters; P_{FV} = final value of parameter; P_{IV} = initial value of parameter

The Effect of Spent Engine oil on the Growth Performance of Amaranthus viridis: The growth performance of *Amaranthus viridis* in the presence of spent engine oil was evaluated over a period of nine weeks. Weekly measurements were taken to monitor plant height (cm), leaf area (cm^2), and the number of leaves. Plant height was measured using a meter rule, starting from the topsoil and extending to the terminal bud. Leaf area was calculated following the method described by Pearcy *et al.* (1989), which involved measuring the length and width of the leaf's longest and widest parts, respectively, and applying the formula 0.5 x L x B (where L represents length and B represents breadth). The number of leaves per stand per container per treatment was determined through visual counting (Pearcy *et al.,* 1989).

Statistical Analysis: Data generated from the study were analyzed using IBM SPSS v 26 (IBM Corporation, New York). Mean values were compared using Analysis of Variance (ANOVA), and their differences were separated using the Duncan Multiple Range Test at a 5% level of significance ($p < 0.05$).

RESULTS AND DISCUSSION

Nutrient content levels of the soil: The nutrient contents of the soil sample are shown in Table 1. As the concentration of spent engine oil increased, the nitrogen content in the soil decreased initially but exceeded the initial levels before the growth of *Amaranthus viridis,* with the control group having the highest initial nitrogen content. The initial nitrogen content in the control group (0ml) was significantly higher compared to other soil samples treated with different amounts of oil. This aligns with the findings of Swapna *et al.* (2021), who observed reduced nitrogen levels in spent engine oil-contaminated soil. Reduced nitrogen levels can affect plant growth and ecosystem functioning, as nitrogen is essential for plant growth and often a limiting factor in soil fertility (Swapna *et al.*, 2021). The decrease in nitrogen levels may have contributed to the reduction in plant height and leaf area we observed in this study, as nitrogen is essential for plant growth and development observed in this study. Nitrogen is a key component of proteins, enzymes, chlorophyll, and DNA, which are essential for plant growth and development. (Tariq *et al.*, 2019). The phosphorus content decreased as the oil concentration increased before planting but increased during the growth of *Amaranthus viridis*. The increased phosphorus content in contaminated soil compared to the control contrasted with the findings of Okonokhua *et al.* (2007), who reported a decrease in phosphorus levels. The contrasting results could be due to factors such as contamination type and extent, soil type, and the presence of other nutrients and microbial communities (Swapna *et al.,* 2021). Phosphorus levels can significantly impact plant growth and soil fertility by influencing energy transfer, root development, DNA and protein synthesis, nutrient availability and uptake, flowering and fruiting, and contributing to soil nutrient cycling (Njoku *et al.,* 2009).

Table 1: Nutrient level of the spent engine oil contaminated soil before and after the growth *Amaranthus viridis*

Nutrients	Concentration of spent engine oil added to the soil(ml)	Initial level of nutrient (without plant (mg/kg))	Final level of nutrient (with plant (mg/kg))	Percentage change (%)
Nitrogen	Control (0ml)	65.21± 0.83a	85.99± 0.64a	31.89
	25ml	57.17 ± 0.48b	84.88 ± 0.21b	48.46
	50ml	59.05 ± 0.18c	83.65 ±0.35c	41.66
	75ml	50.16± 0.21d	82.97 ± 0.06c	65.41
	100ml	48.37 ±0.06e	82.71 ± 0.27c	70.99
F		471.337**	29.453**	
Phosphorus	Control (0ml)	98.58 ±0.52a	121.26 ±1.76d	23.00
	25ml	82.35 ±0.47b	249.22 ±1.97c	202.63
	50ml	80.82 ±0.30c	244.13 ±1.32c	202.06
	75ml	79.95 ±0.11d	282.17 ±3.87b	252.93
	100ml	69.07 ±0.19e	270.94 ±1.29a	292.26
F		1887.890**	1649.316**	
Potassium	Control (0ml)	2.13 ± 0.04c	1.90 ±0.04a	-10.79
	25ml	2.77 ± 0.05b	1.71 ±0.02b	-38.26
	50ml	3.51 ± 0.29a	1.59 ±0.01c	-54.70
	75ml	3.61 ± 0.43a	1.66 ±0.05c	-54.01
	100ml	3.52±0.01a	1.50 ± 0.01d	-57.38
F		15.130**	43.946**	

*Each value represents mean of replicates ± standard deviation; different letter in the same column is statistically significant (ANOVA; Duncan multiple range test, **P< 0.01).*

Increased phosphorus levels can promote plant growth and productivity, but excessive amounts may cause imbalances in soil nutrient levels and contribute to environmental problems such as eutrophication (Okonokhua *et al.,* 2007). This was not observed in this study because there was an overall reduction of *Amaranthus viridis* growth.

The potassium content of the contaminated soil decreased after plant growth. The control group exhibited the highest initial potassium content compared to other treatments. The potassium content without the plant did not show significant differences in the 50ml, 75ml, and 100ml treatments but exhibited significant differences in the control and 25ml treatments. Potassium levels in contaminated soil were lower than those in the control sample, consistent with the findings of Obazuaye and Obueh (2014) and Swapna *et al.* (2021). The decrease in potassium levels can have significant implications for plant growth and soil fertility. Potassium is essential for plant growth as it is involved in processes such as photosynthesis, water use efficiency, and stress tolerance (Nwite and Alu, 2015). Therefore, a decrease in potassium levels in contaminated soil may limit plant growth and productivity. The reduction in potassium levels in contaminated soil due to spent engine oil contamination can be attributed to physicochemical interactions, ion competition, disruption of nutrient cycling, physiological stress, and root damage, all of which can limit plant growth and productivity (Obazuaye and Obueh, 2014). The decrease in potassium levels may have influenced the reduction in the number of leaves and overall plant growth observed in this study, as potassium plays a crucial role in various physiological processes.

The percentages of nitrogen, phosphorus, and potassium contents varied with increasing oil concentration, with the 100ml treatment showing the highest changes. The correlation between the percentage change in nutrient levels and the growth parameters of *Amaranthus viridis* revealed that spent engine oil contamination had a negative impact on the growth parameters of the plant. The observed decrease in nitrogen levels and the subsequent reduction in plant height and leaf area, along with the changes in phosphorus and potassium levels, collectively highlight the detrimental effects of soil contamination on plant growth. These findings are consistent with previous studies that reported similar negative effects of soil contamination on plant growth.

Metal content levels of the soil: Table 2 shows the amounts of sodium, calcium, magnesium, iron, lead, and zinc in the spent engine oil-contaminated soil at the beginning and end of the study. Sodium content decreased with increasing spent engine oil concentration before and after the growth of *A. viridis.* However, sodium levels were found to be higher in the contaminated soil before the growth of *A. viridis* compared to the control after the growth of *A. viridis*, which is consistent with the findings of Obazuaye and Obueh (2014). This indicates that sodium may have been taken up by *Amaranthus viridis* from the soil, resulting in lower sodium levels after plant growth. Excess sodium levels can negatively affect soil structure and plant growth by causing soil compaction and reduced permeability, the decrease in sodium levels due to spent engine oil contamination suggests a potential improvement in soil health. Lower sodium content can help maintain optimal soil structure, prevent soil compaction, and promote better water and nutrient retention in the soil (Obazuaye and Obueh, 2014; Okonokhua *et al.,* 2007). Calcium content decreased in general but remained higher after the growth of *A. viridis* compared to before the growth of *A.viridis.* Contaminated soil showed lower calcium levels compared to the control, in line with Okonokhua *et al.* (2007), but contradicting Obazuaye and Obueh (2014). Calcium is crucial for plant growth and affects soil structure. Decreased calcium levels can result in nutrient deficiency, erosion, and reduced water infiltration, while increased calcium levels can improve soil structure, nutrient availability, and mitigate the negative effects of other contaminants (Okonokhua *et al.,* 2007). These could have contributed to the reduction of *A. viridis* growth observed in this study. Magnesium content decreased in all treatments except the control, magnesium content in the soil was not significantly different between the control and 25ml contaminated soil ($P>0.05$), while significant differences were observed in the magnesium content among the 50ml, 75ml, and 100ml treated soils. Magnesium plays a crucial role in various physiological processes such as photosynthesis, enzyme activation, and nutrient uptake in plants. Decreased magnesium levels can negatively impact plant growth and development, potentially leading to nutrient deficiencies and impaired metabolic functions. Consequently, the reduced magnesium levels observed in the contaminated soil may limit the growth and productivity of *Amaranthus viridis* (Obazuaye and Obueh, 2014). Iron content increased in all treatments, which is consistent with the findings of Okonokhua *et al.* (2007). Iron is essential for plant physiological processes, but changes in its levels can affect plant growth and ecosystem functioning (Gyana and Sunita, 2015). Increased iron levels can promote pollutant degradation, but excess iron can lead to toxicity, nutrient unavailability, and cellular damage (Bashir and Ibrahim, 2017). Lead content increased with spent engine oil concentration, but no significant changes were observed. Similar to the findings of Obazuaye and Obueh (2014), lead levels increased in contaminated soil. Lead is a toxic heavy metal that poses significant health risks to plants, animals, and humans (Seema *et al.*, 2013). Higher lead levels can have detrimental effects on plant growth and ecosystem health by interfering with photosynthesis, reducing nutrient uptake, damaging cell membranes, and reducing soil fertility and microbial activity (Obazuaye and Obueh, 2014). Zinc content increased in all treatments except the 100ml treatment, with the control showing the largest percentage change. While zinc is an essential micronutrient for plants, excess levels can have toxic effects (Seema *et al.,* 2013). Elevated zinc levels can interfere with nutrient uptake and disrupt various metabolic processes in plants, leading to growth inhibition and physiological disorders (Gyana and Sunita, 2015). Therefore, the increased zinc levels in the contaminated soil could have contributed to the reduction in the plant growth of *Amaranthus viridis*. The percentage change in metal levels provides insights into the impact of spent engine oil contamination on plant growth. Elevated sodium levels showed a decrease after planting, suggesting a potential positive effect on plant growth. However, the increase in calcium, magnesium, iron, and zinc levels indicates potential adverse effects on plant growth due to contamination. Lead levels remained relatively constant, suggesting no significant impact on plant growth.

Table 2: Metal levels of the spent engine oil contaminated soil before and after the growth *Amaranthus viridis*

Metals	The amount of spent engine oil added to the soil (ml)	Initial levels of metal before planting (mg/kg)	Final levels of metal after planting (mg/kg)	Percentage change (%)
Sodium	Control(0ml)	75.05 ± 0.06a	64.11±1.27a	-14.57
	25ml	68.29 ± 0.39b	59.13±1.44b	-13.41
	50ml	65.88 ± 0.19c	53.93±0.15c	-18.13
	75ml	63.12 ± 0.23d	51.12±0.17d	-19.01
	100ml	61.84 ± 0.25e	50.98±0.27d	-17.56
F		900.870**	84.625**	
Calcium	Control(0ml)	6.02 ± 0.21a	8.22±0.09a	36.54
	25ml	5.78 ± 0.35ab	7.30±0.13b	26.29
	50ml	5.37 ± 0.01bc	6.36±0.18c	18.43
	75ml	4.85 ± 0.23c	6.91±0.01c	42.47
	100ml	3.85 ± 0.23d	6.69±0.02d	73.76
F		27.999**	90.788**	
Magnesium	Control(0ml)	6.03 ± 0.33a	6.31±0.02a	4.64
	25ml	5.76 ± 0.04a	6.00±0.03ab	4.16
	50ml	5.57 ±0.14ab	5.73±0.39b	2.87
	75ml	5.08 ±0.18b	4.99±0.03c	-1.77
	100ml	4.11 ±0.13c	5.12±0.03c	24.57
F		31.196**	20.623**	
Iron	Control(0ml)	1.98 ± 0.25a	7.53±0.04a	280.30
	25ml	1.98 ± 0.07a	16.65±0.93b	740.90
	50ml	2.25± 0.20b	23.99±0.05c	966.22
	75ml	2.66 ± 0.24b	27.29±0.14d	925.93
	100ml	3.02± 0.16b	30.00±0.15e	893.37
F		10.534*	912.501**	
Lead	Control(0ml)	0.04± 0.01a	0.04±0.00a	0
	25ml	0.04 ± 0.01a	0.04±0.00a	0
	50ml	0.04±0.00a	0.04±0.00a	0
	75ml	0.05± 0.01a	0.05±0.02ab	0
	100ml	0.05± 0.01 a	0.05±0.02b	0
F		1.214ns	6.632*	
Zinc	Control(0ml)	2.06±0.23a	2.11±0.02a	2.42
	25ml	2.31±0.13ab	2.34±0.02b	1.29
	50ml	2.36±0.04ab	2.41±0.02c	2.11
	75ml	2.45±0.04b	2.48±0.03d	1.22
	100ml	2.60±0.03b	2.55±0.02e	-1.92
F		5.253*	110.885**	

*Each value represents mean of replicates ± standard deviation; different letter in the same column is statistically significant (ANOVA; Duncan multiple range test, **P< 0.01, *P< 0.05, and ns: not significant.*

Physicochemical Characteristics of the Soil: The pH, total organic matter and total organic carbon of the spent engine oil-contaminated soil at the beginning and the end of the study are shown in Table 3. The study found that the pH of contaminated soil was higher than the control, aligning with Swapna *et al.*

(2021) but contradicting Okonokhua *et al.* (2007) and Obazuaye and Obueh (2014) who reported no significant pH changes. Soil pH greatly influences soil health, plant growth, and nutrient availability (Jackson and Thounaojam, 2018). Increased pH can negatively affect nutrient availability, making certain micronutrients less accessible to plants, potentially hampering plant growth and yield. Higher soil pH levels may also alter soil microbial communities, impacting soil fertility, nutrient cycling, and overall soil health (Okonokhua *et al.*, 2007; Swapna *et al.*, 2021). In line with Okonokhua *et al.* (2007) and Obazuaye and Obueh (2014), the study revealed that contaminated soil had higher organic carbon content than the control. The increase in organic carbon content can significantly influence soil fertility and productivity by enhancing nutrient availability, soil structure, and microbial activity. Organic carbon is crucial for physical, chemical, and biological soil processes, including nutrient cycling, water-holding capacity, and soil structure formation (Bationo *et al.*, 2007). Consequently, increased organic carbon content can positively impact soil health and productivity.

Table 3: The pH, Total organic matter and Total organic carbon of the spent engine oil-contaminated soil before and after the growth of *Amaranthus viridis*

Parameters	Amounts of spent engine oil added (ml)	Initials levels obtained (mg/kg)	Finals levels obtained (mg/kg)	Percentage change (%)
pH	Control (0ml)	6.10±0.06a	5.29±0.07a	-13.27
	25ml	5.90±0.04ab	5.54±0.05b	-6.10
	50ml	5.88±0.03ab	5.81±0.03c	-1.19
	75ml	5.77±0.06bc	5.83±0.02de	1.03
	100ml	5.58±0.21c	5.96±0.08e	6.81
F		6.250*	45.498**	
Total organic matter	Control(0ml)	2.06±0.23a	6.42±0.03a	211.65
	25ml	2.31±0.13ab	8.07±0.25b	249.30
	50ml	2.36±0.04ab	10.26±0.09c	334.74
	75ml	2.45±0.04b	13.08±0.21d	433.87
	100ml	2.60±0.03b	13.80±0.30e	430.76
F		250.549**	491.251**	
Total organic carbon	Control (0ml)	8.97±0.47a	3.71±0.03a	-58.63
	25ml	20.46±7.71b	5.31±1.18b	-74.04
	50ml	20.11±0.14b	6.09±0.08c	-69.71
	75ml	25.86±0.06c	7.73±0.28d	-70.10
	100ml	31.53±0.30c	7.96±0.08d	-74.75
F		11.702**	240>984**	

*Each value represents mean of replicates ± standard deviation; different letter in the same column is statistically significant (ANOVA; Duncan multiple range test, **P< 0.01, *P< 0.05, and ns: not significant).*

Effect of Spent Engine Oil on Growth Parameters of A.viridis: Figure 2 shows the number of leaves of *Amaranthus viridis* grown in spent engine oil-contaminated soil. In the first week, no significant differences ($P > 0.05$) were observed among treatments. However, throughout the growth period, the control (0ml) consistently exhibited the highest number of leaves. In subsequent weeks, there were variations in leaf numbers, with reductions observed in the control and 25ml treatment after the 6th week, in the 50ml treatment after the 7th week, and in the 75 ml and 100 ml treatments after the 8th and 5th weeks, respectively. These reductions in the number of leaves across various treatments suggest that the toxic or inhibitory effects of spent engine oil on plant growth and development, including leaf formation, can lead to decreased leaf numbers over time.The decrease in the number of leaves in spent engine oil-contaminated soil is similar to findings by Nwadinigwe *et al.* (2019) and Onwusiri *et al.* (2017). Reduction in the number of leaves can diminish photosynthetic capacity, affecting a plant's ability to produce energy and grow (Nwadinigwe *et al.*, 2019). Figure 3 shows the plant height of *Amaranthus viridis* grown in spent engine oil-contaminated soil, demonstrating a general reduction in plant height with increasing soil contamination. However, in week 2, *A. viridis* grown in 100ml spent engine oil-contaminated soil exhibited significantly greater height compared to the 75ml and 25ml treatments. While there were no significant differences in plant heights among the control, 25ml, and 50ml treatments in week 1, significant decreases were observed in the 75ml and 100ml treatments ($P < 0.01$). Throughout weeks 2 to 9, the control consistently showed the highest plant heights ($P < 0.01$) compared to soil contaminated with spent engine oil. From week 7 onwards, no significant differences were observed in the heights of *A. viridis* grown in all spent engine oil-contaminated soil samples ($P > 0.05$). Higher shoot length of plants in soil with lower levels of spent engine oil than those of plants exposed to higher levels of spent engine oil could be due to higher levels of toxicity as a result of higher amounts of the spent engine oil. The reduced *Amaranthus viridis* plant height, observed aligns with findings from Okonokhua *et al.* (2007), Osuagwu *et al.* (2017), and Nwadinigwe *et al.* (2019). The reduction in plant height due to spent engine oil contamination may indicate decreased nutrient absorption and photosynthetic efficiency, leading to nutrient deficiencies, and reduced energy production (Osuagwu *et al.*, 2017).

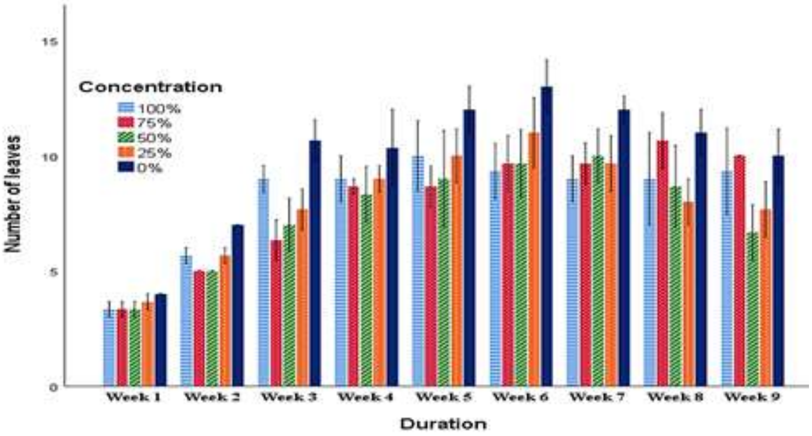

Fig 2: Number of leaves of *Amaranthus viridis* grown in spent oil.

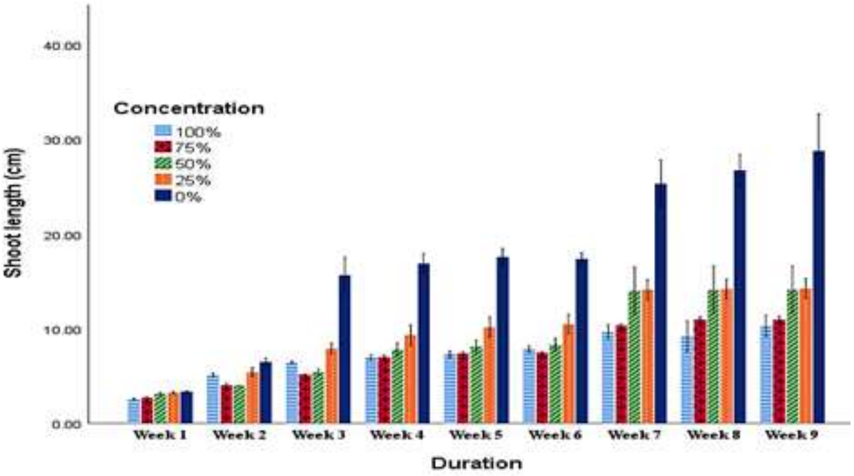

Fig 3: Shoot length of *Amaranthus viridis* grown in spent oil.

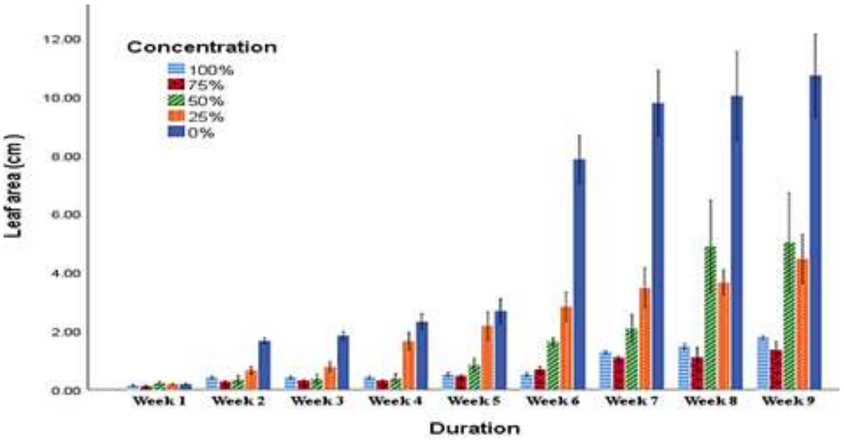

Fig 4: Leaf area of *Amaranthus viridis* grown in spent oil.

Figure 4 shows the leaf area of *Amaranthus viridis* grown in spent engine oil-contaminated soil. In week 1, no significant differences were observed in leaf area among all soil concentrations. However, from week 2 to week 9, the control group consistently exhibited significantly higher leaf area compared to all groups treated with spent engine oil-contaminated soil (25ml, 50ml, 75ml, and 100ml). The leaf area of *A. viridis* decreased with increasing amounts of spent engine oil in the soil throughout the study period, except for a slight non-significant increase observed in the 100ml treatment from week 2 to week 9, after reaching a minimum at 75ml spent engine oil-contaminated soil. The reduced leaf area observed in the contaminated soil could be attributed to several factors, including the toxic effects of contaminants present in the spent engine oil. These contaminants may interfere with the plant's physiological processes, nutrient uptake, and overall growth, leading to reduced leaf area. The similarity of this finding with previous studies by Okonokhua *et al.* (2007) and Onwusiri *et al.* (2017) suggests a consistent pattern of decreased leaf area in response to soil contamination. The decrease in leaf area and the number of leaves can negatively impact a plant's photosynthetic capacity, limiting its ability to produce energy and ultimately affecting its growth (Nwadinigwe *et al.*, 2019).

Conclusion: This study shows that spent engine oil has negative effects on the soil properties and the growth parameters of *Amaranthus viridis*. The study underscores the urgent need to address the environmental hazards posed by spent engine oil pollution, as it jeopardizes ecosystems and poses risks to human and plant well-being. Heightened awareness and proactive measures are essential to mitigate these harmful effects and ensure sustainable agricultural practices.

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