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RESEARCH PAPER

Effect of spent engine oil pollution and liquid organic fertilizer application on soil chemical properties and nutrient contents of Maize (*Zea Mays*)

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Abstract. A trial was conducted to evaluate the effect of spent engine oil (SEO), bio-treated with liquid organic fertilizer, on maize plant growth. The study utilized three concentrations of SEO (0.5 and 10% w/w) and four liquid organic fertilizers (water control, cattle dung, poultry manure and rabbit manure). These factors were arranged in a 3 × 4 factorial setup with three replications in a completely randomized design. Collected data included percentage moisture, dry weight, nutrient content and uptake, heavy metal concentration, and post-harvest soil chemical properties. Soil composite samples on physical and chemical analysis carried out show that the engine oil pollution negatively affected soil pH, total nitrogen, available phosphorus, and exchangeable cations, but it increased total organic carbon before maize cultivation. The percentage moisture and dry weight of the maize plant were not significantly ($p > 0.5$) influenced by engine oil pollution or liquid organic fertilizer application. N, P and Mg content of maize plant were significantly reduced by the engine oil pollution but significantly boosted by organic fertilizer application. Cr and Pb content of the maize were increased with engine oil concentration but decreased with liquid organic fertilizer. Nutrient uptake was decreased with increase in engine oil content but increased with liquid organic fertilizer application. At the end of the experiment, engine oil pollution significantly depressed pH, total N, available P and exchangeable cations, but increased organic C, total hydrocarbon, exchangeable Al and heavy metal content while it was opposite for liquid organic fertilizer. Our findings suggested that soils polluted with SEO should be corrected with the application of organic fertilizers.

Keywords: Spent engine oil; heavy metals; liquid organic fertilizer; nutrient uptake; soil pollution

1. Introduction

In Nigeria, Zea mays is a staple food and one of the most abundant crops. According to FAO reports, Nigeria produced around 4.7 million tons of maize between 1990 and 2015 (Ayinde et al., 2015; FAO, 2017). The consumption of maize in Nigeria is steadily increasing, and in the 2016/2017 planting season, maize production surged to 10.5 million metric tons (Mundi Index,

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2017; Sadiq et al., 2013). Initially introduced in the sixteenth century, maize became the fourth most consumed grain in Nigeria after rice, sorghum, and millet. Currently, Nigeria leads in maize production among African countries and ranks as the 10th largest producer globally (FAOSTAT, 2012; IITA, 2012). The significant increase in maize production in Nigeria primarily stems from expanded cultivated areas rather than improved yields. The harvested area for maize in Nigeria increased from 2.8 to 3 million hectares between 1986 and 2000, and surpassed 6 million hectares in 2011 (Olaniyan, 2015). Approximately 561,397,29 hectares of land were dedicated to corn cultivation, accounting for roughly 61% of Nigeria's total cultivated area in 2017 (FAO, 2017).

However, the careless disposal of used engine oil significantly contributes to environmental pollution (Onwusiri et al., 2017). The contamination of open spaces, farms, gutters, and water drains by used engine oil presents serious challenges for monitoring and control, as it easily seeps into the environment, polluting water and soil (Olugboji & Ogunwole, 2008; Onwusiri et al., 2017). Soil contaminated with used oil becomes unsuitable for agriculture due to nutrient depletion or toxicity, leading to elevated levels of heavy metals such as chromium, tin, lead, and manganese, which exceed plant tolerance thresholds (Emmanuel et al., 2019; Ikhajiagbe et al., 2013). High concentrations of these metals adversely affect seed germination, reduce crop yield, and can result in premature plant death (Ikhajiagbe et al., 2013). Soil contamination from oil spills also hampers the growth of crops like maize, leading to significant negative impacts on food productivity. A study by Murmu et al. (2013) on maize (Zea mays) in acidic soil revealed that organic manure enhances crop productivity, nitrogen utilization efficiency, and soil health. The use of organic wastes, such as cow dung, pig manure, and poultry manure and rubber processing sludge, has been reported to give positive results in the remediation of oil-contaminated soils (Adams et al., 2015; Adesodun, 2004; Okieimen & Okieimen, 2002; Okpashi 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). This study was undertaken to evaluate the effect of spent engine oil pollution and liquid organic fertilizer application on post-harvest soil chemical properties and nutrient contents and uptake of maize.

2. Material and method

2.1. Experimental site

A potted experiment was conducted between March and April 2021 in the Screen House of Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria. The University is situated between latitude 6° 230' 370" and 6° 24' 260" North and longitude 5° 36' 250" and 5° 38' 090" East, at an elevation of 162 meters above sea level. The study location is within the tropical lowland rainforest, characterized by a bimodal rainfall and an annual mean of 2300 mm with an average temperature of 25.1^{o} C. The area falls within the rainforest agro-ecological zone.

2.2. Source of experimental materials

The soil used as potting material was obtained from a composite sample of topsoils (0 – 15 cm depths) collected from Crop Science Experimental Farm, University of Benin. The maize seeds used for the study were 'Oba Super' obtained from Eddy Banger, Benin City, Edo State. Poultry manure, cattle dung, and rabbit manure were obtained from the University Farm Project. These organic materials were cured under shade for four weeks before use, and liquid fertilizer was subsequently prepared from them. The spent engine oil used in the experiment was obtained from a mechanic workshop in Ugbowo, Benin City, Edo State.

2.3. Laboratory analysis

Prior to the filling of polythene bags, samples were collected from each bag separately and bulked together to constitute composite soil sample for physical and chemical analysis. The composite soil samples were air-dried and sieved through a 2mm mesh before analysis. This preparation was carried out before sowing, and after harvest, soil samples were collected separately from each poly bag. The collected soil samples were dried and sieved through a 2 cm mesh, then analyzed for soil chemical properties.

Particle size distribution was determined by the hydrometer method (Bouyoucos, 1951) as modified by Gee and Bauder (1986). Soil pH was determined using a glass electrode pH meter at ratio 1:1 (20 g soil to 20 ml distilled water) following the method described by McLean et al. (1982). Organic carbon content was determined by Chromic acid wet oxidation procedure of Black (1965). Calcium and magnesium were determined volumetrically by the EDTA titration procedure described by Black (1965), while potassium and sodium was determined from the filtrate by flame photometry, following the method described by Black (1965). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by McLean et al. (1982). Available phosphorus in the soil samples was determined using the procedures of Bray and Kurtz (1945). Total nitrogen content was determined using the Kjeldahl digestion, distillation, and titration method.

Effective cation exchange capacity (ECEC) was calculated by summing up the exchangeable bases and exchange acidity (Tan, 1996). Soil bulk density was determined using the core method. Core soil samples collected using core samplers of known dimensions from the field were trimmed in the laboratory to the height of the core and weighed. The core, together with the soil sample, was oven-dried at 105°C for 24 hours and weighed again, while the weight of each core samplers was noted. The mass of the dry soil alone was also noted after oven drying, and the bulk density was calculated using the following relationship:

$$\rho_d = gV \tag{1}$$

where:

ρ_d is Bulk density, g is weight of oven dried soil in grams, V is volume of core cm^3. But volume of core is:

$$V = \pi r^2 h \tag{2}$$

V is the volume of core, π is mathematical constant approximately equal to 3.142, r is radius of core, h is length or height of core. The total porosity of the soil was calculated from the relationship:

$$F_t = \left(1 - \frac{\rho_d}{\rho_p}\right) \times 100 \tag{3}$$

where F_t is total porosity, ρ_d is bulk density and ρ_p is particle density. Dry weights were determined by placing sample aliquots in 10 ml, pre-weighed, clean, dry beakers. The beakers had been pre-dried in an oven at 105°C and then cooled in a desiccator. After cooling for 30 minutes, the weight of the empty beaker was recorded to the nearest 1 mg. Moisture content was determined via a thermogravimetric approach, which involve heating the samples and recording the weight loss due to evaporation of moisture. Nutrient content was determined using mass spectrometry (MS), typically coupled with liquid chromatography (LC) or gas chromatography (GC).

2.4. Experimental design and cultural practices

The experiment involved three rates (0%, 5%, and 10% w/w) of spent engine oil and four types of liquid manure (control, poultry manure, cattle manure, and rabbit manure), laid out in a factorial arrangement and fitted into a completely randomized design, which was replicated three times. Each treatment comprises of three polythene bags, resulting in a total of 12 polythene bags for the experiments.

2.5. Pre-sowing treatment and agronomic practices

Polyethylene bags were filled with 10 kg (12,926 cm^3) of air-dried soil, measured into perforated poly bags measuring 60x75x15 cm and placed on a tray. Designated poly bags for spent engine oil treatment were each thoroughly mixed with 0, 64 and 128 ml representing 0%, 5% and 10% w/w, spent engine oil in the soil, respectively. The soil designated for 0 (zero) had not added pollution. Each Polyethylene bags was watered with the designated liquid fertilizer at a rate of 100 ml per day, while the control group was watered with water alone. Seeds were sown at a rate of three seeds per polyethylene bag. After sowing, watering was done with the designated liquid fertilizer using watering can, and subsequently at three days intervals. Seedlings were thinned two weeks after sowing (WAS). Weeding and pest control were carried out through by hand-picking throughout the experiment duration. The plants were harvested at 6 weeks after sowing, and the aerial portions of each plant were dried at 70^{o}C until a constant weight was achieved.

2.6. Data collection and analysis

Harvested plants were weighed, recorded, and dried in oven at 70°C until a constant weight was achieved. To calculate nutrient uptake and content, multiply the concentration with dry matter per polypot. The data obtained for various variables were analyzed using GENSTAT statistical package for analysis of variance. Significant differences among treatment means were determined using the least significant difference (LSD) at the 5% level of significance.

3. Result

3.1. Nutrient analysis of soil before planting

The physical and chemical properties of soils unpolluted and polluted with spent engine oil, as well as the chemical composition of the organic fertilizers used in the experiment before planting, are presented in Table 1. Both polluted (0%) and unpolluted soils were sandy clay loam. The pH for unpolluted soil (0%) was slightly acidic; however, soil polluted at concentrations of 5% and 10% were moderately and slightly acidic, respectively. Cattle and rabbit manure were slightly acidic, while poultry manure was moderately acidic. the organic carbon (C) content was higher in polluted soil compared to unpolluted soil. Similarly, the organic matter content was higher in polluted soil than unpolluted soil. Total nitrogen (N) decreased with an increase in spent engine oil concentration. The total nitrogen content in both cattle and poultry manure exceeded the critical level.

The available phosphorus (P) decreased as the concentration of spent engine oil increased, but was found to be higher in rabbit manure. Exchangeable calcium levels were below the critical threshold in both polluted soil and unpolluted soil. Magnesium content decreased with increasing spent engine concentration in unpolluted soil, whereas the highest was observed in cattle dung. Potassium (K) content was below the critical value in unpolluted soil but higher in cattle dung. Sulfur (S) was not detected for polluted soil but found only in poultry manure among the organic fertilizers.

Hydrogen ions were as only detected in unpolluted soils, with a concentration of 0.00% observed for organic fertilizers. Aluminum ions (Al^+) were observed exclusively in unpolluted soil and increased with higher concentrations of spent engine oil. Porosity decreased as spent engine oil concentration increased, while the reverse was true for bulk density; however, porosity was not detected in organic fertilizers. Lead (Pb), cadmium (Cd), and chromium (Cr) were detected in both soils and organic manure but at very low concentrations.

3.2. Effect of engine oil pollution and liquid organic fertilizer on maize plant dry matter

The results of effects of engine oil pollution bio-remediated with liquid fertilizer on the moisture content and dry matter of the maize plants were presented in Table 2. The moisture content and dry weight (%) were not significantly affected ($p > 0.05$) by the presence of spent engine oil pollution or the application of liquid organic fertilizer.

Table 1. Physical and chemical properties of polluted soil with spent engine oil and chemical composition of organic fertilizer

Parameters	Polluted soil (% w/w)			LSD (0.05)	Organic fertilizers		
	0	5	10		Cattle dung	Rabbit manure	Poultry manure
Particle size (g/kg)							
Sand	886.00	887.00	889.00	Na	Na	Na	Na
Silt	64.00	62.00	60.00	Na	Na	Na	Na
Clay	50.00	51.00	51.00	Na	Na	Na	Na
Porosity (%)	58.60	56.40	56.20	2.001	Na	Na	Na
Bulk density (g/cm^3)	1.18	1.20	1.31	0.112	Nd	Nd	Nd
pH	5.40	5.00	4.80	0.498	6.50	6.70	6.25
Organic C (g/kg)	17.00	17.60	18.20	0.979	25.80	30.30	28.60
Total N (g/kg)	0.77	0.74	0.72	0.045	1.54	1.04	1.87
Available P (mg/kg)	12.30	10.80	10.30	1.415	16.00	17.00	18.00
Exchangeable cation (cmol/kg)							
Ca	0.66	0.85	0.80	0.160	1.00	1.08	1.22
Mg	0.20	0.34	0.32	0.096	0.50	0.44	0.35
K	0.18	0.31	0.31	0.129	2.12	2.04	0.34
S	Na	Na	Na	Na	0.00	0.00	3.88
H	0.01	0.04	0.35	0.308	0.00	0.00	0.00
Al	0.00	0.05	0.14	0.116	0.00	0.00	0.00
Heavy metals (mg/kg)							
Pb	0.00	0.01	0.02	0.017	0.01	0.01	0.02
Cr	0.00	0.02	0.03	0.027	0.01	0.01	0.01
Cd	0.00	0.02	0.03	0.027	0.01	0.01	0.01

Na - not applicable
Nd - not detected

Table 2. Effect of engine oil pollution and liquid organic fertilizer on maize plant dry matter

Treatment	Moisture content (%)	Dry weight (%)
Engine oil concentration		
0	83.60	16.40
5	66.60	16.80
10	68.40	14.80
LSD (0.05)	Ns	Ns
Organic fertilizer		
Control	70.60	18.30
Cattle dung	83.60	16.40
Poultry manure	66.60	11.20
Rabbit manure	70.90	18.20
LSD (0.05)	Ns	Ns
Interaction	Ns	Ns

Ns: Not significant

3.3. Maize Plant nutrient content under engine oil pollution and organic fertilizer

The nutrient content of maize plant influenced by engine oil pollution and liquid fertilizer is presented in Table 3. Engine oil pollution significantly ($p < 0.05$) affected N, P, K and Mg. The N and P content of maize plants decreased with increasing engine oil concentration. However, the P content of plants from unpolluted soil was identical to that of soil polluted with a 5 % w/w concentration of engine oil. The Mg content showed no clear trend with engine oil pollution concentration. The Mg content of plants from unpolluted soil and those from soil polluted with 5% engine oil concentration were identical and significantly higher than the Mg content of plants from soil polluted with a 5% concentration.

All nutrient content, except for Na, was significantly influenced by liquid organic manure. Plants treated with cattle dung exhibited the highest N content, which was comparable to those treated with poultry manure. Additionally, plant treated with poultry and rabbit manure showed the highest P content. Furthermore, plants treated with organic manure had K content comparable to each other but significantly higher ($p < 0.05$) than control plants. Plant treated with poultry manure exhibited the highest Ca content, surpassing that of the control plants. Mg content was lowest in control plants and highest in those treated with rabbit manure.

Table 3. Nutrient content of maize plant as influenced by engine oil pollution and liquid organic fertilizer

Treatment	Nutrient Content (g/kg)					
	N	P	K	Ca	Mg	Na
Engine oil concentration						
0	22.78	0.38	2.53	0.65	0.48	0.27
5	15.30	0.38	2.50	0.65	0.45	0.21
10	16.07	0.30	2.54	0.61	0.48	0.23
LSD (0.05)	0.522	0.023	0.033	0.041	0.016	Ns
Organic fertilizer						
Control	17.70	0.28	2.40	0.59	0.45	0.21
Cattle dung	18.47	0.29	2.58	0.61	0.46	0.21
Poultry manure	18.22	0.35	2.55	0.64	0.48	0.24
Rabbit manure	17.81	0.35	2.56	0.60	0.49	0.27
LSD (0.05)	0.603	0.036	0.039	0.047	0.009	Ns
Interaction	1.044	0.046	0.067	0.081	0.016	Ns

Ns: Not significant

However, there was a significant interaction between spent engine soil pollution and liquid organic manure on all nutrient content except Na (Table 4). Unpolluted soil that received cattle manure exhibited the highest N, P, K, Ca and Mg content. The P content of unpolluted soil treated with cattle manure was similar to that of unpolluted soil treated with rabbit manure. Additionally, the Mg content of soil polluted with 10% engine oil concentration was identical to that of unpolluted soil treated with cattle dung.

3.4. Heavy metal content of maize plant as influenced by engine oil pollution and liquid organic fertilizer

In Table 5, significant differences were observed among the spent engine oil treatments for Cr, Fe and Pb. Cr and Pb were not detected at 0% pollution, and their highest concentrations was observed at 10% pollution, which was comparable to the levels of observed at 5% pollution. Iron content decreased at 5% pollution but increased at 10% pollution. The application of organic fertilizer significantly influenced heavy metal content ($p < 0.05$). Control and rabbit manure-treated plants exhibited the highest Cr content. Fe and Pb content were highest in the control plants. The interaction between engine oil pollution and liquid organic fertilizer interaction was significant for Fe and Pb content, soil polluted with 10% engine oil without fertilizer treatment had the highest Fe and Pb content (Table 6). However, the Pb content of soil polluted with 10% engine oil concentration and treated with rabbit manure was identical to that of soil polluted with 10% engine without fertilizer treatment in terms of Mg content.

Table 4. Interactive effect of engine oil pollution and liquid organic fertilizer on nutrient content of maize plant

Treatment		Nutrient Content (g/kg)				
Engine oil conc. (%)	**Organic fertilizer**	**N**	**P**	**K**	**Ca**	**Mg**
0	Control	20.60	0.34	2.36	0.60	0.43
	Cattle dungs	25.50	0.40	2.69	0.71	0.52
	Poultry manure	22.07	0.38	2.51	0.65	0.48
	Rabbit manure	22.93	0.40	2.57	0.63	0.50
5	Control	14.50	0.23	2.34	0.53	0.40
	Cattle dungs	15.70	0.27	2.55	0.56	0.46
	Poultry manure	16.00	0.31	2.57	0.60	0.47
	Rabbit manure	15.50	0.30	2.53	0.56	0.46
10	Control	18.00	0.27	2.50	0.64	0.52
	Cattle dungs	14.20	0.20	2.50	0.55	0.41
	Poultry manure	16.60	0.36	2.58	0.67	0.48
	Rabbit manure	15.50	0.35	2.59	0.60	0.52
LSD (0.05)		1.044	0.046	0.067	0.081	0.032

Table 5. Heavy metal content of maize plant as influenced by engine oil pollution and liquid organic fertilizer

Treatment	Cr (mg/kg)	Fe (mg/kg)	Pb(mg/kg)
Engine oil concentration			
0	0.000	70.800	0.000
5	0.110	61.750	0.140
10	0.130	66.150	0.170
LSD (0.05)	0.015	0.494	0.040
Organic fertilizer			
Control	0.090	68.530	0.110
Cattle dung	0.060	64.670	0.070
Poultry manure	0.090	64.900	0.130
Rabbit manure	0.080	66.830	0.090
LSD (0.05)	0.017	0.572	0.016
Interaction	Ns	0.990	0.028

Ns: Not significant

Table 6. Interactive effect of engine oil pollution and liquid organic fertilizer on heavy content of maize plant

Treatment		Iron (mg/kg)	Lead (mg/kg)
Engine oil concentration (% v/w)	**Organic fertilizer**		
0	Control	69.40	0.00
	Cattle dungs	72.80	0.00
	Poultry manure	70.30	0.00
	Rabbit manure	70.70	0.00
5	Control	62.40	0.14
	Cattle dungs	60.60	0.12
	Poultry manure	61.40	0.18
	Rabbit manure	62.60	0.12
10	Control	73.80	0.20
	Cattle dungs	60.60	0.10
	Poultry manure	63.00	0.20
	Rabbit manure	67.20	0.16
LSD (0.05)		0.990	0.028

3.5. Nutrient uptake of maize plant as influenced by engine oil pollution and liquid fertilizer

The nutrient uptake of maize, influenced by engine oil pollution and liquid fertilizer, is summarized in Table 7. The uptake of nutrient by maize plants was significantly affected by engine oil pollution. N and P content were highest in unpolluted soil, while K, Ca and Mg content were highest in soil polluted with a 5% concentration of engine oil.

Table 7. Nutrient uptake of maize plant as influenced by engine oil pollution and liquid fertilizer

Treatment	Nutrient uptake (g/kg)				
	N	**P**	**K**	**Ca**	**Mg**
Engine oil conc (v/w%)					
0	47.61	0.80	5.27	1.39	1.01
5	20.26	0.75	6.68	1.46	1.21
10	21.91	0.36	3.16	0.78	0.59
LSD (0.05)	0.129	0.011	0.019	0.012	0.029
Organic fertilizer					
Control	24.28	0.39	3.24	0.81	0.60
Cattle manure	39.78	0.79	5.01	1.21	0.92
Poultry manure	33.57	0.63	4.51	1.14	0.84
Rabbit manure	48.74	0.94	7.39	1.68	1.38
LSD (0.05)	0.149	0.013	0.022	0.014	0.033
Interaction	0.258	0.022	0.039	0.024	0.057

Plants treated with rabbit manure exhibited the highest N, P, K, Ca and Mg. The interaction between engine oil pollution and liquid organic fertilizer had a significant effect ($p < 0.05$) on nutrient uptake. The uptake of N, P, K, Ca and Mg was highest in soil polluted with 5% engine oil and enriched with rabbit manure (Table 8).

Table 8. Interaction effect of engine oil pollution and liquid organic fertilizer on nutrient uptake

Engine oil concentration (v/w.%)	Organic fertilizer	N (g/kg)	P (g/kg)	K (g/kg)	Ca (mg/kg)	Mg (g/kg)
0	Control	35.64	0.59	4.08	0.81	0.74
	Cattle dungs	57.63	0.90	6.02	1.21	1.18
	Poultry manure	51.96	0.89	5.85	1.14	1.12
	Rabbit manure	45.20	0.80	5.14	1.68	1.00
5	Control	18.85	0.30	3.08	0.69	0.53
	Cattle dungs	32.97	0.53	5.36	1.18	0.97
	Poultry manure	19.52	0.38	3.14	0.73	0.57
	Rabbit manure	89.70	1.80	15.14	3.32	2.76
10	Control	18.36	0.27	2.55	0.65	0.53
	Cattle dungs	28.73	0.29	3.65	0.85	0.60
	Poultry manure	29.22	0.63	4.54	1.18	0.84
	Rabbit manure	11.32	0.13	1.90	0.44	0.39
LSD (0.05)		0.258	0.022	0.039	0.024	0.057

3.6. Post-harvest soil chemical properties as influenced by engine oil pollution and liquid organic fertilizer

The post-harvest soil chemical properties, influenced by engine oil pollution and liquid fertilizer, are detailed in Table 9. Soil polluted at concentration of 5% and 10 % exhibited strong and moderate acidity, respectively. Cattle and poultry manure contributed to moderate acidity, while rabbit manure was had a strong acidic effect. Organic carbon content was higher in polluted soil compared to unpolluted soil, with rabbit manure showing the highest organic carbon content among other organic fertilizer used.

Total N decreased with increasing spent engine oil concentration but remained is above critical levels for polluted soil. Similarly, N levels were above critical levels in all types of organic manure used. Available P decreased with increasing spent engine oil concentration but was higher in cattle manure.

All exchangeable cations, except Mg and Na, were significantly influenced by spent engine oil pollution and organic fertilizer. Calcium levels were below the critical levels in both polluted soil and unpolluted soil. Magnesium content was consistent at 5% and 10 % spent engine oil concentration and was higher in cattle dung. K and Na content remained unchanged between 0% and 10% spent engine pollution, while poultry and rabbit manure exhibited similar effects on Na, which was not significantly influenced by organic fertilizer interaction.

Hydrogen ion concentration was observed to increase with spent oil pollution, with higher levels detected in the control group of unpolluted soils. Conversely, aluminum ion (Al+) decreases as spent engine oil concentration increased. The AI+ levels were similar between the control and poultry manure treatments.

The introduction of spent engine oil into the soil introduced hydrocarbons, with concentrations increasing alongside the oil pollution levels; soils with 0% concentration showed no hydrocarbon presence. In the organic fertilizer treatments, higher hydrocarbon levels were observed in control and poultry manure samples.

The concentration of heavy metals (Fe, Cu, and Cr) increased with highest levels of spent engine oil pollution. Lead (Pb) levels remained consistent between 5% and 10% concentrations

Table 9. Post harvest soil chemical properties as influenced by engine oil pollution and liquid organic fertilizer

Treatment	pH (H_2O)	Organic (g/kg)	Tot. N (g/kg)	Av. P (mg/kg)	Exchangeable Cation (Cmol kg-1)						Total Hc (mg/kg)	Heavy metal (mg kg-1)			
					Ca	Mg	K	Na	H+	Al3+		Fe	Cu	Cr	Pb
Engine oil concentration															
0	5.570	15.860	0.840	8.920	0.740	0.150	0.180	0.120	0.120	0.580	0.000	50.43	22.30	0.010	0.000
5	5.440	25.190	0.780	8.860	0.610	0.140	0.150	0.100	0.170	0.110	24.750	63.65	28.90	0.140	0.170
10	5.560	35.350	0.750	7.430	0.680	0.140	0.180	0.120	0.130	0.070	36.730	48.22	25.05	0.120	0.170
LSD (0.05)	0.060	0.452	0.014	0.055	0.046	Ns	0.014	0.018	0.015	0.009	0.104	0.451	0.237	0.010	0.008
Organic fertilizer															
Control	5.390	20.400	0.740	8.070	0.630	0.130	0.160	0.100	0.150	0.090	22.100	61.67	29.07	0.100	0.150
Cattle dung	5.610	25.490	0.810	8.880	0.690	0.160	0.180	0.120	0.120	0.060	19.680	51.07	24.23	0.070	0.090
Poultry manure	5.540	26.900	0.790	8.300	0.680	0.130	0.170	0.110	0.130	0.090	20.470	51.70	24.33	0.090	0.100
Rabbit manure	5.550	29.100	0.810	8.420	0.710	0.140	0.170	0.110	0.140	0.080	19.730	51.96	24.03	0.090	0.100
LSD (0.05)	0.071	0.522	0.017	0.064	0.053	0.016	0.160	ns	0.017	0.010	0.120	0.521	0.274	0.010	0.009
Interaction	0.124	0.904	0.029	0.111	0.692	Ns	0.028	ns	0.029	0.018	0.208	0.903	0.474	0.021	0.016

Table 10. Interactive effect of engine oil pollution and organic fertilizer on post-harvest soil chemical properties

Engine oil conc (v/w.6)	Organic fertilizer	pH (H_2O)	Org.C (g/kg)	Total N (g/kg)	Avail. P (mg/kg)	Exchangeable cation (cmol/g)				Total HC (mg/kg)	Heavy mental (mg/kg)			
						Ca	K	H	Al		Fe	Cu	Cr	Pb
0	Control	5.40	10.20	0.75	8.02	0.65	0.16	0.14	0.06	0.00	48.50	20.40	0.00	0.00
	Cattle dungs	5.70	18.00	0.88	10.22	0.72	0.20	0.10	0.04	0.00	53.00	24.80	0.00	0.00
	Poultry manure	5.58	16.30	0.85	8.65	0.75	0.18	0.13	0.08	0.00	50.20	22.60	0.01	0.00
	Rabbit manure	5.60	19.30	0.87	8.80	0.82	0.18	0.11	0.05	0.00	50.00	21.40	0.01	0.00
5	Control	5.20	20.60	0.70	8.00	0.53	0.13	0.20	0.13	26.80	67.20	32.60	0.15	0.21
	Cattle dungs	5.52	25.87	0.80	9.20	0.64	0.16	0.16	0.10	23.60	60.10	25.40	0.12	0.16
	Poultry manure	5.50	26.00	0.80	9.00	0.60	0.15	0.14	0.10	24.60	62.30	27.50	0.14	0.15
	Rabbit manure	5.52	28.30	0.81	9.24	0.65	0.17	0.16	0.09	24.00	65.00	30.10	0.15	0.16
10	Control	5.56	30.40	0.78	8.00	0.70	0.18	0.12	0.07	39.50	69.30	34.20	0.16	0.24
	Cattle dungs	5.60	32.60	0.75	7.23	0.71	0.21	0.11	0.05	35.43	40.10	22.50	0.10	0.12
	Poultry manure	5.55	38.40	0.73	7.25	0.68	0.17	0.13	0.08	36.80	42.60	22.90	0.12	0.16
	Rabbit manure	5.53	40.00	0.75	7.23	0.65	0.15	0.14	0.09	35.20	40.87	20.60	0.11	0.14
LSD (0.05)		0.124	0.904	0.029	0.111	0.095	0.028	0.024	0.018	0.208	0.903	0.474	0.021	0.016

of spent engine oil. In organic fertilizer treatments, Fe and Cu levels were higher in control samples and were nearly identical across cattle, poultry, and rabbit manure. For Cr and Pb, levels were similar in poultry and rabbit manure treatments, with higher concentration observed in the control samples.

The interaction between engine oil pollution and liquid organic fertilizer significantly affected the chemical composition of the soil. The soil pH ranged from moderately to strongly acidic in both unpolluted and polluted soil treated with organic fertilizers (Table 10). Organic carbon levels were higher at 10% engine oil pollution when treated with organic fertilizer, whereas total nitrogen levels were generally higher in unpolluted soil treated with organic fertilizer. Available P was notably higher in unpolluted soil, with cattle dung showing the highest levels.

Regarding exchangeable bases, Ca levels were higher in the 0% pollution concentration treated with organic fertilizer, while K content for poultry and rabbit manure was identical in unpolluted soil treated with organic fertilizer. Exchangeable acidity H+ and Al3+, was higher at 5% pollution concentration in the control group, respectively.

Total hydrocarbon was undetectable at 0% pollution concentration when using liquid fertilizer, but at 10% concentrations, levels were notably higher in the control group. The interaction of Fe and Cu with plant was higher at 5% pollution concentration when treated with organic fertilizer compared to other concentrations. Cr was not detected in the control group or with cattle dung at 0% pollution concentration, but levels were higher at 10% pollution concentration in control group. Pb was also undetected at 0% pollution concentration when using liquid fertilizer, but levels were notably higher at 10% pollution concentration in the control group.

3.7. Discussion

The trial demonstrated that the spent engine oil pollution and application of liquid organic fertilizer had tremendous effects on nutrient content, uptake, dry matter, and yield of maize plants. Odjegba and Sadiq (2002) observed similar findings their work on spent engine oil and liquid fertilizer application. However, the differential response of maize plants to the various treatments could be attributed to variation in the physical and chemical properties of the spent engine oil concentration and liquid organic fertilizer used in the experiment.

According to Nwite and Alu (2015), spent engine oil affects the physicochemical properties of the soil, increasing bulk density and reducing gravimetric water content, total porosity, and hydraulic conductivity. Additionally, available phosphorus, exchangeable potassium, magnesium, sodium, and calcium were lowered compared to the control. The presence of spent engine oil in soil also introduce heavy metal elements, as noted by Njoku et al. (2012) who identified aluminum (Al), chromium (Cr), tin (Sn), lead (Pb), manganese (Mn), nickel (Ni), and silicon (Si) among the contaminants.

Nutrient uptake and content for elements such as N and Mg were observed to be highest at 0 % concentration and in the control mixed with liquid organic fertilizer. Okonokhua et al. (2007) suggested that spent engine oil has no significant effect on pH and soil texture, but it does increase organic carbon and nitrogen while decreasing phosphorus due to the contamination. It was also observed that rabbit and poultry manure mixed with spent engine oil showed more improvement compared to other fertilizers used in the experiment, which aligns with the findings of Jones and Edington (1968) who treated spent engine oil-polluted soil with organic fertilizer.

4. Conclusion

The application of liquid organic fertilizer to soil affected with spent engine oil greatly improved soil quality. This practice not only improved soil chemical properties and nutrient content but also increased nutrient uptake by maize plants, leading to enhanced growth and the quality of maize crop.

Amending spent engine oil-polluted soil with liquid organic fertilizer, particularly derived from rabbit and poultry manure, is recommended to boost crop production and convert contaminated sites into productive agricultural areas. Therefore, we advocate for the correction of engine oil-polluted soils using organic fertilizers, especially those derived from rabbit and poultry manure.

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