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The Effects of Spent Engine Oil on Soil Properties and Growth of Maize (*Zea mays L.*)

[1]OKONOKHUA, B O; [2]IKHAJIAGBE, B; [3]ANOLIEFO, G O; [1]EMEDE, T O

[1]*Dept. of Crop Science, University of Benin, Benin City, Nigeria. osarobo2002@yahoo.ca*
[2]*Raw Materials Research and Development Council, Abuja, Delta State Office, PMB 95075, Asaba, Nigeria. ikhaj@yahoo.com*
[3]*Dept. of Botany, University of Benin, Benin City, Nigeria.*

ABSTRACT: The effect of spent engine oil (SEO) on soil properties and growth of maize (*Zea mays* L.) was investigated. Five treatments (0.0, 0.2, 0.4, 0.6 and 0.8 l/kg) of the spent oil were applied to soil in perforated poly bags with maize stands at four weeks after sowing. Soil analysis showed that SEO had no effect on both the pH and texture of the soil. Organic C, N and Mg in the contaminated soils increased compared to the control. There was decrease in concentration of P due to soil contamination. Heavy metals (Fe, Cu, Zn and Pb) concentrations of soil increased with increasing concentration of oil. Plant height, root number and root length of maize plants grown in the contaminated soils were adversely affected. The grain yield of the plants in the contaminated soils was significantly reduced. @JASEM

The disposal of spent engine oil (SEO) into gutters, water drains, open vacant plots and farms is a common practice in Nigeria especially by motor mechanics. This oil, also called spent lubricant or waste engine oil, is usually obtained after servicing and subsequently draining from automobile and generator engines (Anoliefo and Vwioko, 2001) and much of this oil is poured into the soil.

There are relatively large amounts of hydrocarbons in the used oil, including the highly toxic polycyclic aromatic hydrocarbons (Wang *et al*., 2000). Also, most heavy metals such as V, Pb, Al, Ni and Fe, which were below detection in unused lubricating oil, have been reported by Whisman *et al*. (1974) to give high values (ppm) in used oil. These heavy metals may be retained in soils in the form of oxides, hydroxides, carbonates, exchangeable cations, and/or bound to organic matter in the soil (Yong, *et al*., 1992). Nevertheless, this is dependent on the local environmental conditions and on the kind of soil constituents present in the soil-water system.

Ekundayo *et al*. (1989) have shown that a marked change in properties occurs in soils polluted with petroleum hydrocarbons, affecting the physical, chemical and microbiological properties of the soil. Oil pollution of soil leads to build up of essential (organic C, P, Ca, Mg) and non-essential (Mg, Pb, Zn, Fe, Co, Cu) elements in soil and the eventual translocation in plant tissues (Vwioko *et al*., 2006). Although some heavy metals at low concentrations are essential micronutrients for plants, but at high concentrations they may cause metabolic disorders and growth inhibition for most of the plant species (Fernandes and Henriques, 1991). However, plants respond differently to pollutants. Anoliefo and Vwioko (1995) reported that the contamination of soil with spent engine oil caused growth retardation in plants, with the effect more adverse for tomato (*Lycopersicom esculentum*) than pepper (*Capsicum annum* L.).

Maize (*Zea mays* L.), a major cereal in Nigeria and many African countries, was chosen for this study because it has become increasingly popular and most farmers have adopted its cultivation. This study aims to evaluate the effects of spent engine oil on soil properties and growth of maize.

MATERIALS AND METHODS

The experiment was conducted at the experimental farm of the Faculty of Agriculture, University of Benin, Benin City (Lat. 6˚ 36´, Long. 6˚ 19´). Topsoil (0-6 cm), obtained from the experimental farm was properly mixed, put into 40 by 40cm perforated polythene bags to a weight of 15kg. This was watered and allowed to settle.

The maize seeds, DMR-W, were obtained from the Agricultural Development Project, Benin City, Edo State, Nigeria. The viable seeds were determined by the flotation method. Three maize seeds were planted in each bag and thinned down to two seedlings after two weeks.

Spent engine oil was obtained as pooled used engine oil, from heavy-duty vehicles, at different motor mechanic workshops located in Benin City. The experiment was laid out as a completely randomized design in 4 replications. Five treatments of SEO (0.0, 0.2, 0.4, 0.6 and 0.8 l/kg) were applied to the soil with maize stands at 4 weeks after planting. Some of the oil drained off through pores underneath the bags in all treated soils. In order to determine the concentration of SEO (C_{SEO}) retained in soil, drainage of oil from the 0.2 l/kg treated soil, which lasted for 3 days, was recorded; and the concentration retained in the soil thereafter gave the value 0.15 l/kg. This was calculated using the formula:

$$C_{SEO}\ in\ soil\ (l/g) = \frac{V_a - V_b}{m}$$

V_a = volume of SEO poured into the soil (litres)
V_b = volume of SEO that drained away from soil (litres)
m = mass of soil (kg)

Weeding was done by handpicking throughout the experiment. Manual watering was not done. This was because the frequency and the amount of rainfall (649.4mm) as determined in Nigeria Institute for Oil Palm Research, Benin City Station, during the experimental period, was in the required range (600-900mm) for maize growth (Purseglove, 1975).

Random soil samples were taken (0-15cm depth) at the experimental farm just before loading of the polythene bags. Also, soil samples were collected from each treatment at the end of the experiment. All soil samples collected were bulked, air-dried and passed through a 2mm sieve for physicochemical analysis.

Growth and yield measurement: Survival counts were taken per bag per treatment after 4 weeks of contamination with the spent oil and the percentage survival calculated by the formula:

$$\frac{\text{No of seedlings that survived}}{\text{No of seedlings contaminated}} x100$$

At maturity, other growth parameters were measured including plant height, leaf area, stem girth, root number, ear length and yield. Plant height was obtained by measuring the plant from the soil level to the collar of the uppermost leaf. The leaf area was determined by measuring the length and width (at the widest point) of each leaf. The product of this was multiplied by a correction factor of 0.75 to cater for leaf shape (Watt, 1973). The stem girth, number of primary root and length of ear were also measured. In other to determine yield, all the maize cobs for each treatment were harvested and weighed after removing the husk. The data were analyzed using the analysis of variance (ANOVA) technique and the Duncan's multiple range test was used to compare the means (Alika, 1997).

Soil analysis: Soil samples were analyzed prior to experimentation and after harvest of crops for some chemical properties. Particle size and texture of soil samples were determined using the method of Bouyoucous (1951). The soil pH was measured by means of a glass electrode pH meter by dipping the glass electrode into a 1:1 soil-water suspension. Exchangeable cations, Na, K, Ca and Mg were determined by using methods of Udo and Ogunwale (1986), whereby the ammonium acetate extract topsoil samples were subjected to flame photometry and atomic absorption spectrophotometer. Total N was determined by Kjel-dahl method (Bremner, 1965). Available P was determined by Bray 1 method (Bray and Kurtz, 1945). Organic C was determined using the adapted Walkley and Black (1934) method (IITA, 1979). Concentrations of heavy metals (Fe and Cu, Zn and Pb) were determined by atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

*Effects of spent engine oil on soil properties***:** The results of the soil analysis before and after harvest are shown in Table 1. There was no significant difference (P>0.05) in the soil pH between the control and the contaminated soil. However, pH ranges were between 4.5 and 4.7. Soil pH is a major factor influencing the availability of elements in the soil for plant uptake (Marschner, 1995). Many metal cations are more soluble and available in the soil solution at low pH (below 5.5) including Cd, Cu, Hg, Ni, Pb, and Zn (McBride, 1994). The retention of metals to soil organic matter is also weaker at low pH, resulting in more available metal in the soil solution for root absorption. The organic C and N contents of the contaminated soils increased compared to the control (Table 1). This resulted from application of the spent oil to soil. Crude oil, from which the engine oil is produced, contains principal elements such as oxygen, nitrogen and sulphur other than hydrogen and carbon (Selley, 1998). The oil increased the Mg content of the soil, the degree however decreasing with increasing oil concentrations (Table 1). P was reduced in the oil contaminated soils compared to the control and this agrees with the findings of Ogboghodo *et al*., (2004). The soil texture (sandy soil) was not significantly affected by the SEO (Table 1). Spent engine oil used in the present study contained 1.3mg/l of Cu and 5.2mg/l of Fe before application to soil (Table 2). Thus, the oil-contaminated soils contained more heavy metals than the control (Table 3) and the values increased with increasing oil concentration. This implies that soils retain heavy metals in spent engine oil even during drainage. This behaviour may result from certain mechanisms such as chelation and sorption by soil. Yong (2001) reported that there is a bonding relationship between contaminants and soil surfaces due to sorption forces. The contaminant solutes in solution become attached to the surface of the soil (solids) particles through mechanisms, which seem to satisfy the forces of attraction from the soil solids (surfaces) (Yong *et al*., 1992). The heavy metals, being positively charged, are electrostatically attracted to the negative charges on the clay particles (Yong, 2001). Organic complexation of metals may also occur when the solid state humic material binds metals into a ring-typed structure (ligand molecule) most commonly a chelate (Harrison, 1996; Sparks, 2003).

Table 1: Effects of SEO on soil physico-chemical properties

SEO	pH	C	N	P	Na	K	Ca	Mg	H	Al	ECEC	Clay	Silt	Sand
(l/kg)		(%)	(%)	(ppm)			(meq/100g)						(%)	
0.00_{BP}	4.6	2.07	0.08	5.76	0.18	0.15	0.72	0.64	0.20	0.40	2.29	2.0	1.8	96.2
0.00_{AH}	4.7	2.37	0.24	5.86	0.18	0.15	1.04	0.08	0.10	0.50	2.76	2.0	3.8	94.2
0.2	4.6	3.55	0.36	5.28	0.17	0.12	0.84	0.80	0.20	0.40	2.59	2.0	1.8	96.2
0.4	4.5	3.81	0.38	4.78	0.22	0.14	1.04	0.48	0.20	0.60	2.68	2.0	2.8	95.2
0.6	4.7	3.85	0.39	4.56	0.21	0.14	1.28	0.42	0.10	0.50	2.47	2.0	2.8	95.2
0.8	4.7	3.68	0.37	4.85	0.23	0.14	0.96	0.40	0.20	0.40	2.23	2.0	2.8	95.2

*BP - Before Planting; *AH - After Harvest

Table 2: Analysis of spent engine oil

Elements	Concentration (mg/l)
Cu	1.3
Fe	5.2

Table 3: Concentration of heavy metals in soil before and after contamination

Concentration (l/kg soil)	Fe	Cu	Zn	Pb
		(ppm)		
0_{BP}	3.57	3.20	1.36	0.29
0_{AH}	25.50	3.50	1.85	0.13
0.2	83.50	4.80	1.88	0.53
0.4	134.00	7.00	2.13	0.55
0.6	228.00	8.60	2.59	0.7
0.8	301.00	12.10	2.81	0.81

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Effect of spent engine oil on maize growth: Heavy metals present in spent lubricants can accumulate in plants and affect metabolic processes (Prasad and Prassad, 1987). This suggests why the present study showed reduction in vegetative growth of the maize plants at 2 weeks after contamination of the soil with the oil. Some leaves of the plants in the contaminated soils experienced chlorosis, necrosis, and curled upwards from their tips. Some of these symptoms such as stunted growth and chlorosis have been attributed to Zn toxicity by Lepp (1981). Significant decreases in leaf area were recorded in 0.6 and 0.8 l/kg treatments. Plant height, root length and root numbers of the control plants were significantly greater ($P < 0.05$) than those in the contaminated soils (Table 4). This agrees with the findings of Anoliefo and Vwioko (1995) who reported that spent engine oil in soil creates unsatisfactory conditions for plant growth ranging from heavy metal toxicity to insufficiency in aeration of the soil.

There was reduction in the ear length of the maize plants in the contaminated soils however this was only significant ($p < 0.05$) when compared between the control and 0.8 l/kg contaminated soil. There was also significant decrease ($P < 0.05$) in the grain yield of the crop plants between those grown in the control (195.11g/plant) and contaminated soil (Table 4). The reduction was as low as 18.09g/plant in the 0.8 l/kg treatment. Similarly, Wang *et al*., (2002) reported that maize decreased in dry matter yield by up to 68% when grown in metal-contaminated sites with Cd, Cr, Zn, Pb, Cu and Mn in soil.

Table 4: Growth and yield parameters of maize plants at maturity

Concentration (l/kg)	Plant Height (cm)	Leaf area (cm2)	Stem girth (cm)	Root Number	Root length (cm)	Ear Length (cm)	Grain yield (g)
0.0	119.50^{a}	155.65^{a}	3.40^{a}	27.25^{a}	31.55^{a}	19.38^{a}	195.11^{a}
0.2	80.55^{b}	149.82^{ab}	3.15^{a}	18.75^{b}	15.43^{b}	15.48^{ab}	75.25^{b}
0.4	61.10^{bc}	92.06^{ab}	3.08^{a}	13.38^{bc}	9.19^{bc}	9.75^{ab}	25.24^{c}
0.6	49.00^{bc}	73.16^{bc}	2.50^{a}	9.78^{c}	8.23^{c}	7.18^{ab}	23.65^{c}
0.8	41.60^{c}	69.38^{bc}	2.60^{a}	8.63^{c}	8.29^{c}	6.30^{b}	18.09^{c}

**Parameters marked with same letter superscripts are not significantly ($p < 0.05$) different from one another.*

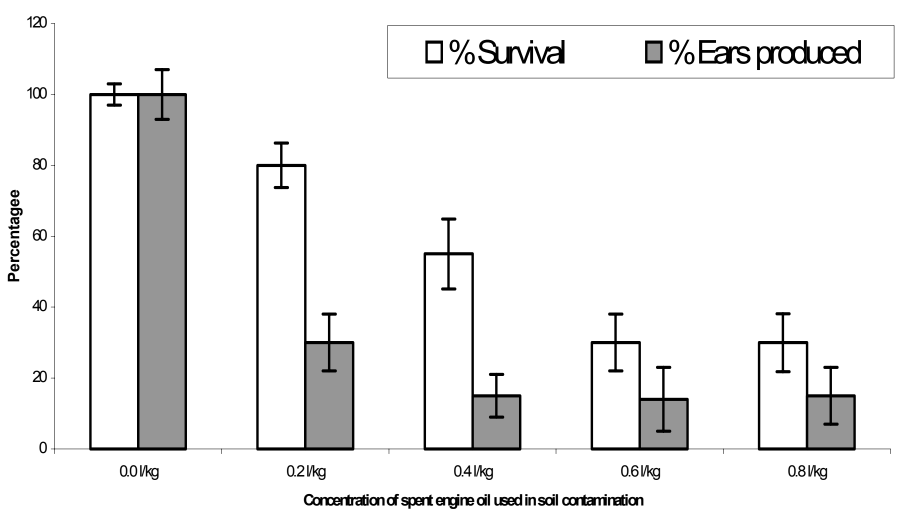

Fig. 1: Percentage survival and ears of maize plants at maturity

At maturity, it was observed that while all (100%) of the control plants survived, percentage survival reduced from 80% in 0.2 l/kg soil to 30% in 0.8 l/kg soil (Fig 1). Percentage of ears produced by maize plant decreased from 100% in the control to 15% in 0.8 l/kg soil (Fig 1). The physical properties of oil imposed some stressful conditions, which may have interfered with water uptake and gaseous exchange (Amakiri and Onofeghara, 1984). These conditions in turn result in physiological drought (Anoliefo and Edegbai, 2000). The leaves of plants in the contaminated soils curled upwards from their tips and withered, resulting to death of most of the plants (Fig 1). Damage to maize plants may also have resulted from increase in temperature due to the dark nature of contaminated soils. It was observed in this study that the contaminated soils were darker than the control, and dark soils absorb more heat than light ones. Donahue *et al*. (1990) reported that some black coal mining wastes and dark coloured oil-shale residues reached temperatures of 65-70^{o}C, which are lethal to many plants that would otherwise grow in those soils. Soils polluted with waste-oil result in the soil remaining unsuitable for crop growth and depending on the degree of contamination, type of soil and soil environment, the soil may remain unsuitable for crop growth for months or years until the oil is degraded to tolerable levels (Atuanya, 1987).

Conclusion: The present study showed that spent engine oil adversely affected soil properties. Maize plants that survived in contaminated soils became stunted. Consequently, the need to encourage the protection of farmlands and their surroundings against indiscriminate disposal of the oil cannot be overemphasized.

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