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Phytoremediation Potentials of Sorghum (Sorghum Bicolor), Sunflower (Helianthus Amarus) and Fluted Pumpkin (Telifaria Occidentallis) On Spent Engine Oil Polluted Texturally Contrasting Soils

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Abstract

Phytoremediation potentials of Sorghum (Sorghum bicolor), Sunflower (Helianthus amarus) and Fluted pumpkin (Telifaria occidentallis) on spent engine oil polluted texturally contrasting soils was evaluated in the glasshouse belonging to the Department of Soil Science, University of Nigeria, Nsukka. Three texturally contrasting soils: Sandy loam (SL), Loamy sand (LS) and Sandy clay loam (SCL) were potted with a polythene bag and polluted with 10% w/w (122ml/kg), 20% w/w (245ml/kg) and 0% w/w (0ml/kg) of spent engine oil. The experiment was a 3x3x3 factorial replicated thrice in a completely randomized design (CRD). The soil was thoroughly mixed with spent engine oil and allowed to stay for three weeks to allow for proper absorption of the engine oil. Thereafter, air dried crushed and sieved poultry manure was applied to each polythene bag at a rate of 40 t/ha. The spent engine oil- organic manure mixture was watered to field capacity 3 times per week for two weeks after which the crops were sown. Soil samples were collected and analyzed at the end of the study which lasted for 12 weeks, to determine the total hydrocarbon in the soil after planting. The data on soil parameters were subjected to analysis of variance (ANOVA) using GENSTAT. The results showed that the Total Petroleum Hydrocarbon (TPH) was higher in the 20% polluted soil as it increases with the level of pollution and was highest in the soil in which pumpkin was planted and least in the soil in which sunflower was planted. The study concluded that Sunflower has better phytoremediation potential for spent engine oil-polluted soils than Sorghum and Fluted pumpkin.

Keywords: phytoremediation; soil type; spent engine oil; sorghum; sunflower; pumpkin

Introduction

Soil is a vital part of the natural environment as most plants require a soil substrate to provide water and nutrients and also influences the distribution of plant species and provides a habitat for a wide range of organisms (Rajesh et al., 2016) [24]. To ensure sustainable agricultural production and maintenance of biodiversity soil health has to be properly managed. One of the threats to soil health and sustainable agricultural production is soil pollution. Soil pollution is an alarming issue worldwide and thus became the theme of world soil celebration on 5th December, 2018. Soil pollution is the introduction of chemical or any substances in an abnormal proportion thereby posing adverse effects to any non-targeted organisms and also making the soil infertile (Rodriguez et al., 2018) [25]. It is the undesirable alteration in the physical, chemical and biological characteristics of the soil which may cause long or short-term damage by changing the growth rate of plant and animal species and causing direct or indirect harm to humans or other living organisms (Erneste et al., 2017) [12]. Based on scientific evidence, soil pollution can severely degrade the major ecosystems services provided by soil thereby reducing food security either by reducing crop yields due to toxic levels of contaminant or by making the crops produced from polluted soil unsafe for human and animals' consumption (Rodriguez et al., 2018) [25]. Petroleum hydrocarbon though is very useful in many ways in our society today tends to have disastrous impact on agricultural production because of its effect on agricultural soils causing harm to the soil body; organisms, depleting of nutrients and organic matter (Ayotamuno et al., 2006) [6]. Pollution of the soil with spent engine oil is an unintentional release of liquid petroleum hydrocarbon into the environment and can be caused majorly by leakage storage tanks or engines either in mechanical shops or in farmlands while using farm machineries, land disposal of petroleum wastes and accidental spills (Eman 2008) [11]. The bulk of this influx is due to industrial waste as leakage from engines, incorrect operation of valves and discharge of oily wastes. Several factors are important with regard to the initiating event of the spent engine oil spill. When spent engine oil spill event occurs, one of the most important predictor of impact is its locations and the spillage rate (Stephanie et al., 2014) [28]. According to Michel and Fingas (2016) [22], the permeability of the oil into the soil is dependent on the texture of the soil as sand and gravel are the most permeable while materials such as clay, silt, or shale are impervious. Pollution of the soil with spent engine oil affect the soil; limiting its nutrient level and fertility status (Abii, 2009) [2]. According to previous studies (e.g Kayode et al., 2009 [21]) these spent engine oil pollutants often resulted to poor aeration of the soil due the displacement of air from the spaces between the soil particles, retarded growth of plants, leading to chlorosis of leaves and dehydration of plants. The hydrocarbon found in spent engine oil are large and complex molecules and persistent in nature and may require a strong reagent to counteract their effects on agricultural soils (Kayode et al., 2009 [21]). Thus, various processes to remove oil from contaminated areas have been developed and these includes; use of boom, dispersants and skimmers, oil water separator or by use of different kind of sorbent material (Husseien, 2009 [18]). However, the main limitation of all these techniques are their high cost and inefficient trace level adsorption (Husseien, 2009 [18]). Remediation of contaminated soil is the application of suitable techniques in the removal of contaminants present in soils which could be heavy metals and aromatic hydrocarbon (Dike 2013 [9]). Phytoremediation, which consists in the use of plants and their associated microbiota to reduce the concentration or toxic effects of the contaminants in the environment (Ali et al., 2013 [4]), has drawn great interest from the scientific community, because, compared with traditional remediation methods, this technique has low cost, high decontamination efficiency and is environmentally less impactful (Tangahu et al., 2011 [29]; Ali et al., 2013 [4]). Phytoremediation is an emerging technology that uses various types of plants to remove, transfer, stabilize and/or degrade contaminants from the soil-water environment offering an alternative to conventional clean up techniques (Fulekar, 2016 [15]). It has also been called green remediation, botano-remediation, agroremediation and vegetative remediation (Bruce, 2001 [7]). Root depth and morphology as a plant characteristic affect phytoremediation. A phytoremediation system capitalizes on the synergistic relationship among plants, microorganism, water and soil that have evolved naturally in wetlands and upland sites over millions of years. In the biological sequences that transform contaminants to neutral compounds, plants contribute inherent enzymatic and uptake processes that can recycle or sequester the organic molecules they encounter (Ahalya and Ramachandra, 2006 [3]). Phyto-remediation is considered to increase oil attenuation by the plant taking in small molecular hydrocarbons. Aerating the soil to increase aerobic degradation of oil provides root exudates for microbial co-metabolization of oil components and other molecules as the oil content in the oil site was almost reduced to the level of the control (Wang et al., 2013 [32]). In phytoremediation, the root system of the plant enhances the process and this process is useful in fine soils and is better than biological methods that do not work well in fine soils (Esin and Ayten, 2011 [13]). Phytoremediation is an inexpensive technique which require minimum maintenance. Different plants such as grasses, legumes etc. has been used as phytoremediators (Abdul Hameed et al., 2018 [1]). The efficacy of plants to remediate spent oil polluted soil depends amongst other factors on the nutrient availability in such soil. The objective of this study is to evaluate the phytoremediation potentials of some common plants on soils of contrasting textures polluted with spent engine oil.

Materials and Methods

Description of Study Area

This study was carried out at the glasshouse belonging to the Department of Soil Science, University of Nigeria Nsukka located at approximately by latitude 6°54’N and longitude 7°24’E within the derived savanna zone of eastern Nigeria with an altitude of 447.26 m above sea level (Oko-Ibom and Asiegbu, 2006 [23]). The area is characterized by a humid tropical climate with wet (April- October) and dry (November-March) seasons, and a mean annual rainfall of 1750 mm bimodally distributed with peaks in July and September; mean annual maximum (day) and minimum (night) temperatures of 31°C and 21°C respectively (UNN Meteorological Station, 2010).

Relative humidity ranges between 70 to 80% (Oko-Ibom and Asiegbu, 2006 [22]) and falls below 60% during the period of Harmattan- a short period of about three weeks of hazy and very dry weather usually from December through January (Asadu et al., 2001 [5]).

Procurement of Plant Materials and Spent Engine Oil

Three soils with different textural classes were collected from Ekwegbe and University of Nigeria teaching and research farm both of which are in Nsukka. Two of these soils were obtained from Ekwegbe, Nsukka while one was collected from the University of Nigeria teaching and research farm close to the glasshouse. The three different soils were taken to the laboratory for mechanical analysis (Gee and Or, 2002) [16] to determine their textural classes (Table 1).

Soils	*Coarse sand (%)*	*Fine sand (%)*	*Total sand (%)*	*Silt (%)*	*Clay (%)*	*Textural class*
1	26.76	23.88	86.40	3.30	10.30	Loamy sand
2	9.10	45.90	64.00	14.00	22.00	Sandy clay loam
3	11.90	44.50	56.40	33.30	10.30	Sandy loam

Table 1: Particle size distribution of the soils before any pollution.

Sorghum and Fluted pumpkin seeds were purchased from the farmers in the school market while the seeds of Sunflower were obtained from Niger state. Spent engine oil was procured from university of Nigeria Nsukka mechanic engineering shop. Poultry manure was obtained from university of Nigeria Nsukka poultry farm belonging to the Department of Animal Science.

Experimental Setup

The study involves three factors. The factors are phytoremediating plant types, soils of different textures and three levels of crude oil pollution. The phytoremediating plant types are Sorghum bicolor (Sorghum), Telferia occidentalis (Fluted Pumpkin) and Helianthus annus (Sunflower). The soils used for the study were air-dried, crushed and passed through a 2 mm sieve and 4kg of the soils were weighed into eighty-one perforated polythene bags. The soil samples were further subjected to three levels of spent engine oil pollution- 122 ml/kg (10% w/w), 245 ml/kg (20% w/w) and 0 ml/kg serving as control. The soil samples were thoroughly mixed with spent engine oil and allowed to stay for three weeks to allow for proper absorption of engine oil. Thereafter, air-dried, crushed and sieved poultry manure was applied to each polythene bag at a rate of 40t/ha. The soil-spent engine oil-organic manure mixture was watered to field capacity 3 times per week for two weeks after which the seeds of sorghum, pumpkin and sunflower were sown. Sorghum, pumpkin and sunflower seeds were sown into 27 perforated polythene bags each at the rate of three seeds per bag but the seedlings were thinned down to one plant per bag two week after planting. The experiment was executed as 3x3x3 factorial with three replications giving a total of eight-one experimental units. The plants were watered to field capacity thrice in a week and allowed to grow freely in the glasshouse for three (3) months.

Sampling Technique

Disturbed soil samples were collected from each polythene bag using a knife at a depth of 0-20cm, air-dried and sieved through 4.76mm and 2.0mm sieve. Soil that passed through 2mm sieve were used for determination of total hydrocarbon.

Laboratory Analysis

Total hydrocarbon (THC) content of the soil was extracted from 5g of air-dried soil samples using n-hexane (USGS, 2014) [31]. The mixture was shaken vigorously using mechanical shaker for 30mins and then allowed to settle for 10mins. The solution are then filtered and the filtrate diluted by taking 1ml of the extract into 50ml of n-hexane. The THC content in the sample was then read on Atomic Absorption Spectrophotometer at a wavelength of 420mm.

Statistical Analysis

Data generated after the experiment was subjected to analysis of variance (ANOVA) in split plot design (SPD) using Genstat Discovery Software, Edition 4. Differences were deemed significant at 5% probability level. The mean was separated using least significant differences (LSD).

Results and Discussion

Main effect of spent engine oil, soil type and phytoremediators on total petroleum hydrocarbon

The results show that the effect of pollution status on total petroleum hydrocarbon was significant, the effect of soil type on total petroleum hydrocarbon was significant and the effects of phytoremediators on total petroleum hydrocarbon was also significant (Table 2). The total petroleum hydrocarbon (TPH) increases with increasing level of pollution with 0% pollution having 0.00 mgkg-1 TPH, 10% pollution having 505.57 mgkg-1 and 20% pollution having 609.90mgkg-1. The total petroleum hydrocarbon was highest in sandy loam soil (399.79 mgkg-1) and lowest in loam sand soil (350.95 mgkg-1) indicating that sandy loam soil retained more of the spent engine oil than other soils. The total petroleum hydrocarbon was highest in pumpkin soil (389.88mgkg-1) and lowest in sunflower soil (359.17 mgkg-1) indicating that there is still higher amount of spent engine oil in the pumpkin soil than other soil therefore sunflower is the best phytoremediator as sunflower has been found to have high biomass at varying exposure concentration which resulted in increased uptake of heavy metals with the accumulation of the metals higher in the roots of the plants followed by shoot (Fulekar, 2016 [15]) but according to Johnson et al 2010 [20], the efficiency of sunflower plant in cleaning contaminated soils was at the early stage of their growth. Buildup of heavy metal like Nickel and Lead in sunflower induces stress and causes chlorophyII loss; Nickel been highly toxic and responsible for chlorophyII degradation causes deviation from the normal green colour of the plant and this is caused by more rapid injury in the cell membrane (Saima et al., 2010 [27]) then sorghum which picked up at first but started encountering some setbacks which could be due to progressive decrease in the germination of S. bicolor as crude oil contamination increased and the decrease was due to penetration of the oil into the seeds which is believed to have killed the embryos or may act as a physical barrier around seeds thus preventing or reducing both oxygen and water from entering the seed (Iheme et al., 2017 [19]). According to Ronke et al., 2015 [26] germination rate was low in 20% concentration of spent oil during the fifth day of planting of the seeds but it has moderate percentage of germination at 10% concentration of spent oil at day twelve of planting. While pumpkin is the least but is still suitable plant for phytoremediation as its long vines and broad leaf system that covers the soil serve as “life mulch” creating suitable environment for hydrocarbon degrading microorganisms activity (Godwin and Peter, 2014 [17]). Pumpkin can survive in soil with high metal and can serve as a phytoremediator for soils contaminated with lead and cobalt and to a lesser extent cadium; the plant accumulate the copper and chromium metals more in the shoots while lead and cobalt metals were accumulated more in the shoots than in the roots (Dahiru, 2014 [8]) but higher engine oil pollution levels delayed emergence and inhibits the germination of some seeds and this was attributed to poor aeration and absorption of the oil by the seed causing them to be swollen and slimy (Ekpo and Ebeagwu, 2009 [10]).

Ps %	*TPH (mgkg-1)*	*Soil type*	*TPH (mgkg-1)*	*Phyto*	*TPH (mgkg-1)*
P0	0.00	Sandy clay loam	364.73	Pumpkin	389.42
P10	505.57	Loam sand	350.95	Sorghum	366.88
P20	609.90	Sandy loam	399.79	Sunflower	359.57
F-LSD(0.05)	0.07	F-LSD(0.05)	0.08	F-LSD(0.05)	0.07

Ps = pollution status, p0 = 0% pollution, p10 = 10% pollution, p20 = 20% pollution, TPH = total petroleum hydrocarbon, F-LSD (0.05)= Fisher’s Least Significant Difference at 5% probability, phyto= phytoremediator.

Table 2: Main effect of spent engine oil, soil type and phytoremediators on total petroleum hydrocarbon.

Interaction Effects on the total petroleum hydrocarbon

The interactions effects were all significant (Table 3 and 4). The total petroleum hydrocarbon was highest in sandy loam soil in which pumpkin was planted (421.24 mgkg-1) and was lower in loamy sand soil in which sunflower was planted (342.35 mgkg-1) and was lowest in sandy clay loam soil in which sorghum was planted (329.14 mgkg-1). It was highest at 20% polluted sandy loam soil (658.02 mgkg-1) and lowest in 10% polluted loamy sand soil (468.96 mgkg-1) and was higher in the 20% polluted sunflower (645.25 mgkg-1) indicating that at 20% pollution, sorghum was the best phytoremediator while at 10% pollution sunflower was the best; was lower in the 10% polluted sunflower (432.25mgkg-1)then the highest value of TPH (688.10 mgkg-1) was obtained from 20% polluted sandy loam soil in which pumpkin was planted and the lowest value (359.39mgkg-1) was obtained from 10% polluted loam sand soil in which sunflower was planted.

Soil type	***Phyto***	***TPH (mgkg-1)***	***Soil type***	***Ps%***	***TPH (mgkg-1)***	***Phyto***	***Ps%***	***TPH (Mgkg-1)***
SCL	Pumpkin	400.78	SCL	P0	0.00	Pumpkin	P0	0.00
	Sorghum	329.14		P10	506.40		P10	551.26
	Sunflower	364.26		P20	587.78		P20	617.00
LS	Pumpkin	346.24	LS	P0	0.00	Sorghum	P0	0.00
	Sorghum	364.26		P10	468.96		P10	533.29
	Sunflower	342.35		P20	583.89		P20	567.44
SL	Pumpkin	421.24	SL	P0	0.00	Sunflower	P0	0.00
	Sorghum	407.23		P10	541.34		P10	432.25
	Sunflower	370.89		P20	658.02		P20	645.25
F-LSD(0.05)		0.12	F-LSD(0.05)		0.93	F-LSD(0.05)		0.93

SCL = sandy clay loam, LS = loam sand, SL = sandy loam, p0 = 0% pollution, p10 = 10% pollution, p20 = 20% pollution, F-LSD (0.05) = Fisher's Least Significant Difference at 5% probability, phyto= phytoremediator.

Table 3: Effects of the different interactions on total petroleum hydrocarbon.

Soil type	***Phyto***	***Ps%***	***TPH(mgkg-1)***
SCL	Pumpkin	P0	0.00
	Sorghum		0.00
	Sunflower		0.00
	Pumpkin	P10	593.14
	Sorghum		455.65
	Sunflower		470.42
	Pumpkin	P20	609.21
	Sorghum		531.78
	Sunflower		622.36
LS	Pumpkin	P0	0.00
	Sorghum		0.00
	Sunflower		0.00
	Pumpkin	P10	485.03
	Sorghum		562.46
	Sunflower		359.39

	Pumpkin	P20	553.70
	Sorghum		530.32
	Sunflower		667.65
SL	Pumpkin	P0	0.00
	Sorghum		0.00
	Sunflower		0.00
	Pumpkin	P10	575.61
	Sorghum		581.45
	Sunflower		466.95
	Pumpkin	P20	688.10
	Sorghum		640.22
	Sunflower		645.73
F-LSD(0.05)			1.61

SCL = sandy clay loam, LS = loamy sand, SL = sandy loam, p0 = 0% pollution, p10 = 10% pollution, p20 = 20% pollution, F-LSD (0.05)= Fisher's Least Significant Difference at 5% probability, phyto= phytoremediator.

Table 4: Effects of the interaction of soil types, phytoremediators and different levels of spent engine oil pollution on the total petroleum hydrocarbon.

Conclusion

The study was carried out to assess three different phytoremediators on three different texturally contrasting soils with different levels of pollution. From the findings level of pollution and soil type affects the effectiveness of the phytoremediators; at 10% pollution, sunflower planted on loam sand soil gave the best result while at 20% pollution Sorghum planted in loam sand soil gave the best result. Sunflower can therefore serve as a better phytoremediator when the rate of pollution is not very high and when the affected soil is loamy sand.

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