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Research Article

Trace metal components of *Gambaya albida* (Linn.) grown in soils contaminated with spent lubricating oil

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Abstract

The trace metal components of *Gambaya albida* seedlings grown in spent engine oil contaminated soils were evaluated in Asaba, Nigeria in 2010 for nine weeks (late April to June) in a pot experiment. Five crude oil levels (0.00, 2.07, 4.15, 6.23 and 8.30% w/w) in soil constituted the treatments. The results showed that spent oil contaminated soils significantly led to the buildup of trace metals including lead, chromium, iron, nickel and cadmium when compared with values obtained for both soil and plant tissues of *G. albida* seedlings grown in the uncontaminated soils. Values of metals from the oil treated soils, and plant tissues grown there were significantly ($p \leq 0.05$) higher relative to values obtained in the untreated soils. The study has demonstrated that spent engine oil contamination of soil leads to a gradual buildup of trace metals which when absorbed by *G. albida* shoots and roots could be potentially toxic and harmful hence constituting health risk if consumed as food by man and other animals.

Key words: Trace metals, *Gambaya albida*, spent engine oil, bioaccumulation, health risk.

INTRODUCTION

Plants generally are susceptible to oil exposure directly or indirectly (Raskin et al., 1994; Benson and Ebong, 2005: Ogbo et al., 2006; Omosun et al., 2009; Agbogidi, 2011a). Delayed seed emergence, growth depression and stunting as well as yield reduction have been reported severally by various authors for various crop plants and tree species (Agbogidi and Eshegbeyi, 2006; Vwioko et al., 2007; Sharifi et al., 2007; Anoliefo et al., 2008). Reasons adduced for these effects include poor wettability and aeration of the soil, loss of seed viability, absorption of the applied oil by the soil that came in contact with the seeds which penetrated the seed embryos, creation of stressful conditions which affect metabolic activities including physiological drought and anatomical aberrations (Ernst et al., 1992; Omosun et al., 2008; Agbogidi, 201lb; Agbogidi et al., 2011a; Hribabu and Sudha, 2011; Mrigakhi and Ashalata, 2012) as well as the presence of heavy metals like arsenic (As), Zn, Co, Fe, platinum (Pt), Cd, Cl, mercury (Hg), Mo, Mn, Ni are known to be essential for normal plant growth and development since they are constituents of many enzymes and other proteins in low quantities. These same elements however, become toxic to most plants at elevated concentrations resulting in growth inhibition and toxicity symptoms and consequently, resulting in the degeneration of major cells, tissues and organs of plants and animals that depend on them stemming from the fact that they are toxicologically stable due to their persistence in the environment (ATSDR, 1992; Meinz, 1999; Hall, 2002; Doom et al., 2004; Adjia et al., 2008; Edet et al., 2008; Dahunsi et al., 2012). Cobb et al. (2000) and Osuji and Onojake (2004) noted that constant exposure to high concentration of heavy metals from oil is one of the greatest problems associated with oil pollution. Haribabu and Sudha (2011) and Nkwocha et al. (2011) also maintained that consumption of food crops contaminated with heavy metals could lead to serious systematic health problems in the body of the affected persons.

Engine oil is a refined product of crude petroleum oil. It is a mixture of hydrocarbons. When produced, it is pure but impurities may be incorporated into it through viscosity improver, deformants, antioxidants and antiwear/extreme pressure additives (Agbogidi, 2010). Engine oil is used in transmission fluids, vehicle crankcase, lubricating oil, gearbox, and synthetic oil that has outlived its usefulness as a result of extensive usage, storage or spillage and becomes contaminated by physical or chemical impurities (Ernst, 1992; Agbogidi, 2010). Such oil contains many toxic and environmentally harmful substances including heavy metals and toxic polyhydrocarbons (Sharifi et al., 2007). Spent engine oil (waste engine oil) has been reported as one of the major and most common oil contaminants (Anoliefo and Edegba, 2000). It is usually obtained after servicing and subsequently draining used oil from automobiles and generator engines (Agbogidi and Ilondu, 2012). The motor oil picks up a number of additional components from engine wear such as iron, steel, particles, copper, lead, zinc, barium and cadmium, sulfur, water, dirt as well as ash (Jesusal et al., 2007). As a result of the additives and contaminants in used engine oil, its disposal can be more environmentally damaging than even the crude oil pollution (Perira and Barbeora, 2009). The disposal of spent oil into gutters, water drains, open vacant plots and farmlands in Nigeria is a common phenomenon and it is mostly done by auto-mechanics and allied artisans with workshops on the road side and open places.

G. albida commonly called African white star apple belongs to the family Sapotaceae. It is a native of Nigeria, Ghana, Kenya, Sierra Leone, and Sudan (Keay, 1989). The botany, distribution, taxonomy, ecology and economic importance of this indigenous tree species have been extensively discussed by Agbogidi and Ejemete (2005). Ige and Gbadamosi (2007) noted that the fleshy and juicy fruits of G. *albida* are popularly eaten when mature and they are potential sources of soft drink as: the fruits contain fatty acids, proteins, vitamins and oil. Different parts of plant including the bark, roots, stems, leaves, seeds and fruits are used in the treatment of a variety of disorders such as malaria, heart diseases and stomach disorders (Keay, 1989). The tree also serves some ornamental purposes; it is a useful shade tree in homes and nursery sites. The wood is useful for construction work and as fire wood. Although studies have been carried out on the effects of oil on tree plants (Terge, 1984; Vwioko et al., 2007), there is paucity of information on the metal concentration of seedlings. It is against this back ground that a study as this has been conducted to evaluate trace metal components of *G. albida* seedlings grown in soil contaminated with spent engine oil with a view to establishing baseline information on this and to ascertain the threat on this multipurpose indigenous species.

MATERIALS AND METHODS

Study area

The experiment was carried out in 2010 in Asaba, Nigeria in 2010 for nine weeks (late April to June). It was a pot study in a greenhouse at the Research Farm of the Department of Forestry and Wildlife, Delta State University, Asaba, Nigeria. Asaba is located within the tropical rain forest zone at latitude 6° 14'N and longitude 6° 49'E of the equator. The area is characterized with a total annual rainfall of 1,955 mm, mean monthly rainfall of 1586 mm; mean monthly soil temperature at 100 cm depth is 31.4℃ and means monthly sunshine of 4.7 h (Asaba Meteorological Station, 2009).

Source of soil sample

Soil sample (top soil) was collected from the *Gmelina aborea* plantation behind the Department of Forestry and Wildlife, Delta State University Asaba Campus.

Source of seedlings

Seedlings of G. *albida* (10 weeks of age) were obtained from the nursery of the Department of forestry and Wildlife, Delta State University, Asaba Campus.

Source of spent lubricating oil

The spent engine oil was collected from randomly sampled 10 mechanic workshops in Asaba, Delta State and mixed together.

Experimented design

Randomized Complete Block Design (RCBD) was used with three replicates for each treatment.

Soil analysis

Composite soil sample was collected from 0 - 20 cm depth with augur prior to treatment application. The samples were air-dried in a room temperature of 25 - 27°C for four days and then passed through a 2 mm mesh sieve and neatly packed in a properly labeled air-tight polythene bags for physio-chemical analysis at the National Institute for Oil Research (NIFOR) near Benin-City, Edo State. The particle size distribution was determined by the hydrometer method (Bouyoucous, 1951) while bulk density was by core method (Blake and Hartge, 1986). Soil pH was determined in distilled water using a soil: liquid ratio of 1:1, Electrical conductivity was measured by a conductivity bridge (Chandos Conductivity Model A19 Bridge) (Obi, 1990). Phosphate-Phosphorus was measured in soil extracts by the ascorbic acid method (IITA, 1979; Obi, 1990). Total nitrogen was determined by the regular Macro-Kjeldahl digestion technique (Jackson, 1964). Nitrate-nitrogen was determined by the phenoldisulphonic acid method (Esu, 1999), Organic carbon was measured by the wet combustion method (Walkley and Black, 1934) and converted to organic matter by multiplying the values of organic carbon by a factor of 1.724 following the procedure of Jackson (1964). C/N ratio was calculated by dividing %carbon values by that of the total nitrogen following the procedure of Esu (1999). Exchangeable calcium and magnesium were determined on atomic absorption spectrophotometer while sodium and potassium were determined on flame photometer (Udo and Ogunwale, 1986): ammonium acetate extracts of soil samples were used in these exchangeable bases determination (Obi, 1990). Determination of exchangeable acidity (H^+ and Al^{3+}) was by KCl extraction method (McLean, 1965). Total Exchangeable Bases (TEB) was calculated by adding the values of all the exchangeable cations (Ca, Mg, Na and K) (IITA, 1979). Total Exchangeable Acidity (TEA) was calculated as the sum of exchangeable H^+ and Al^{3+} ions (IITA, 1979). Effective Cation Exchangeable Capacity (ECEC) was calculated by adding the values of the TEB and TEA. The base saturation (BS) was calculated by dividing the values of TEB by the ECEC and multiplying by 100 following the methods of Agbogidi (2006).

Procedure

The top soil used was thoroughly mixed with the appropriate spent oil level before the poly pots was filled up with the contaminated soil and the control without oil treatment. The levels of spent engine oil used were 0.00, 2.07, 4.15, 6.23 and 8.30%. The experiment was replicated three times with five treatments. The seedlings were watered to field capacity immediately after transplanting them and afterwards, every other day. The set up was monitored for 9 weeks after transplanting (WAT).

Plant tissue analysis

At the ninth week, the seedlings were harvested and were separated into shoots and roots. These were oven dried at 85°C for 24 h to get their dry weights following the procedure of Agbogidi and Eshegbeyi (2006). The plant tissues were ground to a powdered state. One gram of each of the powder was weighed into a conical flask for wet ashing which involved decomposition of the plant tissue in a mixture of strong acids comprising nitric, sulphuric and perchloric of 50°C in a furnace for 4 h until grey coloured indicating that complete ashing has been achieved (Obi, 1990) before subjecting them to analysis for heavy metals by atomic absorption spectrophotometer at the Nigeria Institute for Oil Palm Research (NIFOR) near Benin City in Edo State. After ashing, Na and K were determined by flame photometer (Association of Official Analytical Chemist (AOAC) (1985). The heavy metals: Pb, Cr, Fe, Ni, and Cd were determined by atomic absorption spectrophotometer (AAS) (Association of Official Analytical Chemist (AOAC) (1985). Phosphorus was determined by calorimeter method (Obi, 1990). Total exchangeable bases (TEB) were calculated by adding the values of all the exchangeable cations (Ca, Mg, Na and K). Effective cation exchangeable capacity (ECEC) was calculated by adding the values of the TEB and total base saturation (BS) was calculated by dividing the values of TEB by the ECEC and multiplying by 100 following the above stated authors for soil analysis.

Statistical analysis

All the data collected were subjected to analysis of variance while the significant means were separated with the least significant difference using SAS (2005).

RESULTS AND DISCUSSION

Table 1 shows the soil physio-chemical properties before the experiment. The soil is sandy loam in texture with

Table 1. Physiochemical properties of soil before experiment.

Soil properties	Values
Sand (%)	84.60
Silt (%)	6.92
Clay (%)	8.48
pH (H_2O)	6.20
Organic matter gkg^{-1}	2.64
Total N	0.9
Available P ($mgkg^{-1}$)	8.27
Exchangeable cation (cmo/kg^{-1})	
Ca	1.30
Mg	1.16
K	0.21
Na	0.43
CEC (cmo/kg^{-1})	15.20
% BS(Base saturation)	20.4

Table 2. Physico-chemical properties of soil as affected by spent motor oil in soil.

Parameters	Values
Sand (%)	96.0
Silt (%)	0.9
Clay (%)	3.1
Soil pH	5.8
Textural class	Sandy Loam
Electrical conductivity (µg/cm)	102.4
Organic carbon (%)	1.28
Organic matter (g/kg^{-1})	2.84
Total N (%)	0.02
C/N	64.0
Available P (mg/kg)	36.41
Ca^{2+}(cmol/kg)	1.66
Mg^{2+} (cmol/kg)	0.64
Nat (cmol/kg)	0.16
K^{+} (cmol/kg)	0.21
H^{+} (cmol/kg)	0.83
Al^{3+} (cmol/kg)	0.05
TEB	2.67
TEA	0.88
ECEC (cmol/kg)	3.55
Base saturation (%)	75.21
Trace elements (%)	1.6

characteristics of 84.60% sand, 6.92% silt and 8.48% clay. The pH 6.2 indicated that the experimental site is slightly acidic. Both the organic matter (2.64 gkg^{-1}) and total nitrogen (0.9 gkg^{-1}) are relatively low (Table 1). The soil physico-chemical properties as affected by the presence of spent lubricating oil are presented in Table 2. Treatment had no significant effect ($P \geq 0.05$) on soil physical properties. However, visual observation showed that plots that received spent oil treatment reduced water infiltration and percolation in the soil. This resulted in water accumulating in small pools. Air-drying of the impacted soils took relatively longer time. On drying, the soil gave a cemented waxy appearance which more or less repelled or resisted water /rewetting. This result indicated that spent oil in soil has a significant effect on oil properties like nitrogen content, pH, carbon and presence of trace heavy metals. Metals present included iron, zinc, copper, lead, cadmium, manganese, nickel and chromium. Mean levels of the trace metals in soil and plant tissues after treatment with spent lubricating oil were significantly higher when compared with values before oil application to soil.

Table 3. Trace metal contents ($mgkg^{-1}$) of soil in Asaba as affected by spent engine oil level.

	Trace metal contents				
Oil level % (w/w)		**Cr**	**Fe**	**Ni**	**Cd**
0.00	0.02	1.12	0.03	0.79	0.02
2.07	0.10^{d}	3.09^{d}	1.04^{d}	4.23^{d}	0.98^{d}
4.15	0.15^{c}	1.14^{c}	1.86^{c}	5.79^{c}	1.18^{c}
6.23	0.26^{b}	5.26^{b}	2.54^{b}	7.81^{b}	1.69^{b}
8.30	0.32^{a}	7.03^{a}	3.57^{a}	10.64^{a}	2.03^{a}

Means with different letters are significantly different at ($p \leq 0.05$) level of significance using Duncan's multiple range tests.

This observation is in harmony with earlier reports of Atuanya (1987) and Agbogidi and Egbuchua (2010) who noted that oil in soil has deleterious effects on the biological, chemical and physical properties of the soil depending on the dose, type of the oil and other factors The trace metal contents of soil in the study area are presented in Table 3. Generally, there was a buildup of trace metals in the soil. Soil content of Pb, Cr, Fe, Ni and Cd was significantly ($P \leq 0.05$) higher in soils contaminated with spent engine oil when compared with values obtained from all the identified metals in the control plots. The level of Pb in all the treatments was comparatively low compared to the values recorded for other trace metals (Table 3). In the same vein, the level of metal buildup increased with the level or concentration of the spent oil applied indicating that at 2.0.5, a buildup of trace metals was also obtained in the shoots of the test plant subjected to crude oil treatment relative to those grown in the uncontaminated soils (Table 4). Shoots of *G. albida* plants exposed to 8.30% oil treatment recorded the highest levels of Pb (3.92 mg kg^{-1}), Cr (8.24 mg kg^{-1}), Fe (12.29 mg kg^{-1}), Ni (13.97 mg kg^{-1}) and Cd (12.26 mg kg^{-1}) and all these values were significantly ($p \geq 0.05$) higher than the values obtained for 6.23% w/w and finally those of the control pots (Table 3). Table 4 shows the trace metal content of G. *albida* seedling as influenced by spent engine oil application to soil. Similarly, higher values of trace metals were recorded for *G. albida roots* grown at 30% w/w of the oil while the least values obtained in 0.00% w/w of oil treatment.

Table 4. Trace metal contents (mg kg^{-1}) in shoots of *Gambaya albida* seedlings as affected by spent engine oil in soil.

	Trace metal contents				
Oil level % (w/w)	**Pb**	**Cr**	**Fe**	**Ni**	**Cd**
0.0	0.09^{e}	0.43^{e}	2.86^{e}	1.78^{e}	1.41^{e}
2.07	0.10^{d}	3.45^{d}	6.24^{d}	5.86^{d}	4.23^{d}
4.15	0.15^{c}	4.68^{c}	8.13^{c}	7.25^{c}	6.33^{c}
6.23	0.83^{b}	6.13^{b}	10.56^{b}	10.87^{b}	9.01^{b}
8.30	0.92^{a}	8.24^{a}	12.29^{a}	13.97^{a}	12.26^{a}

Means with different letters are significantly different at ($p \leq 0.05$) level of significance using Duncan's multiple range tests.

Table 5. Trace metals contents (mgkg-1) in plant roots of G. abide seedlings as affected by spent engine oil.

	Trace metal contents				
Oil level % (w/w)	Pb	Cr	Fe	Ni	Cd
0.0	0.12[e]	0.38[e]	1.03[e]	1.84[e]	0.09[e]
2.07	1.22 [d]	3.19[d]	3.07[d]	5.02[d]	4.00[d]
4.15	1.87[c]	4.22[c]	4.00[c]	6.87[c]	3.26[c]
6.23	2.09[b]	5.5 [b]	4.61[b]	8.43[b]	4.02[b]
8.30	3.12[a]	7.42[a]	5.72[a]	11.04[a]	5.01[a]

Means with different letters are significantly different at ($p \leq 0.05$) level of significance using Duncan's multiple range tests.

The observed buildup of trace metals in the spent engine oil contaminated soil has been previously reported by Agbogidi et al. (2007), Edet et al. (2008), Omosun et al. (2009) and Agbogidi and Egbuchua (2010). Apart from its significant effects on soil, crude oil and its products have been shown to affect plants, their growth, development and yields and could also lead to elimination of vegetation cover and subsequent soil erosion. Zenk (1996) and Edet et al. (2008) reported that most heavy metals which were usually below detection in unused lubricating oil give high mg kg^{-1} with the incorporation of dispersants, pressure additives, antioxidants etc. The high rate of contamination from spent oil as a result of increased automobiles, epileptic power supply leading to higher patronage of generators, may cause a lot of damage to plants, man and his animals who depend directly or indirectly on plants. Trace metal poisoning or contamination could lead to water pollution (lakes, streams, rivers including ground water). Ota (2009) and Haribabu and Sudha (2011) noted that toxic metals contamination of soil, aqueous waste streams and ground water cause major environmental and human health problems. Large agricultural soils could be contaminated by trace metals which could render such lands/soils unproductive and apart from decimating agricultural lands, increase the already existing food insecurity in Nigeria particularly and generally, the world over (Maheshwari et al., 2010). Elevated heavy metal concentration in the soil can lead to enhanced crop intake and excessive metals in human nutrition which can lead to acute gastrointestinal and respiratory damage as well as those acute heart, brain and kidney damage (Wang et al., 2000; Gilbert et al., 2003). Chanery et al. (1997) reported that chronic diseases have been reported in humans exposed to long term trace metal uptake including local effects on skin and mucous membranes as well as various systematic effects on the intestines. Klan et al. (2011) further stated that the known fatal effects of heavy metal toxicity include damaged or reduced mental and central nervous functions and lower energy levels. They also cause irregularities in blood composition and badly affect vital organ such as kidney and liver. The long term exposure of trace metals results in physical, muscular and neurological degenerative processes that cause brain disorders, muscular dystrophy (progressive skeletal muscle weakness),and multiple sclerosis (a nervous system disease that affects brain and spinal cord) (IOSHIC, 1999).

CONCLUSION

The trace metal components of G. *albida* grown in soils contaminated with spent engine oil were evaluated in Asaba, Nigeria. The result showed that there was a gradual buildup of trace metals including both in the soil and plant tissues (shoots and roots) of G. *albida* with increasing oil level.

The trend of the trace metals buildup in the oil contaminated soil was 8.30 > 6.23 > 4.15 > 2.07 > 0.00 in all the trace metal identified. This trend depicts that that metal accumulation in soil and plant tissues of G. *albida* seedlings grown in spent lubricating oil is oil-level-dependent. From the findings of this study, it is hereby recommended that care should be taken as trace metal pollution constitutes health risk to the rural environment.

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