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CAN *TITHONIA DIVERSIFOLIA* (Hemsl). A. GRAY, A PAN-TROPIC INVASIVE WEED SPECIES, CLEANUP SPENT LUBRICATING OIL POLLUTED SOILS?

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ABSTRACT

Two pot trials were conducted in the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan between March and June 2005, to evaluate the phytoremediating potential of *Tithonia diversifolia* in spent oil polluted soil to enhance the agricultural productivity. The study was a completely randomized design with three replicates. Varying pollution levels were created by administering spent lubricating oil at 0, 50, 100, 150 and 200 ml per 4-kg soil in pots. Two *Tithonia* seedlings were transplanted into each pot and were monitored for 12 weeks. At commencement of the two trials, lead concentrations in the soil averaged 3.78 mg/kg and 37.75 mg/kg in the control and in 200-ml treatment respectively, and cadmium concentrations averaged 0.73 mg/kg and 2.05 mg/kg in the control and 200-ml treatment respectively. At the end of the two trials, lead content was reduced to 0.00 and 11.88 mg/kg and cadmium content was reduced to 0.00 to 0.43 mg/kg in the control and 200-ml treatments respectively. *Tithonia* seedlings were able to absorb lead and cadmium in the polluted soils, and contents in the root were more than contents in the shoot. The lead and cadmium contents in the shoot compared to the root were about 54% and 30% respectively. The implication of the results for the quality of vegetable produced at urban and peri-urban roadside and wetland gardens is discussed.

KEY WORDS: Cadmium, Lead, Phytoextraction, Pollution, *Tithonia*.

INTRODUCTION

In Nigeria, thousands of oil spillage incidences have occurred since the inception of oil exploration. Oil spillage was identified as one of sources of heavy metal pollution of the environment (Rayment, 1995). Invariably, oil spillage damages the soil, water and both plants and animals. Consequent upon its contents of lead, oil pollution renders soils unproductive for years after spillage, reducing the growth performance of plants (Dale *et al.*, 2006). Therefore, plant growth and establishment, and re-vegetation of polluted sites can serve as indicators for soil recovery (Obilo and Ogunyemi, 2005).

Pollution from spent lubricant is one of the environmental problems in Nigeria and obviously more widespread than crude oil pollution (Edebiri and Nwaokwale, 1983; Odjegba and Sadiq, 2002). Spent lubricant is carelessly let into the environment after servicing and draining of automobile and generator engines. The pollutants in spent oil that are of health and environmental concerns include heavy metals, polycyclic aromatic hydrocarbons (PAHs), and chemical additives like amines, phenols, benzenes, calcium, zinc, lead, barium, manganese, phosphorous, and sulphur (Smith *et al.*, 2006). Spent oil, apart from being a direct environmental pollutant, produces by-products

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on combustion that are also pollutants. Kreuz (1969) reported that sulphur dioxide and nitrogen oxide which has been identified as some of the fall out products of combustion process of spent oil are known to be important causes of acid pollution, capable of being deposited hundreds of kilometres from the source, thus causing acidification in soils, lakes and rivers.

Not only do heavy metals interfere with performance of plants, Chang (1992) reported that bioaccumulation of lead in the human body is implicated in impaired respiration and also cause constipation, anaemia, swelling of the brain, paralysis and death, while that of cadmium is implicated in hypertension and cardiovascular diseases. Needleman *et al.,* (1996) reported that lead can have biochemical effects on the synthesis of haemoglobin and cause acute or chronic damage to the nervous system, reproductive system, kidney, joints, gastrointestinal tract and loss of 20% intelligence quotient (IQ) at blood level of 10-12 µg/dl in young children. Cadmium is reported to be bio-persistent and has effect on renal dysfunction in human after a long-term exposure (CDC, 1991; Ahumada, 1998).

For the implication of heavy metal pollutions on food production and human health, it is compelling to seek less sophisticated method of remediating the contaminated soils. Adesiyan and Osuji (1993) reported that the least dramatic, but most effective removal process of oil from an environment is by simple evaporation which can remove up to 5% of oil slick volume. Other methods include chemoremediation, phytoremediation, bioremediation, compost remediation, excavation and land-filling. Peralta-videa *et al.* (2004) described the plant-mediated removal or hyper-accumulation of contaminants from polluted waters and soils as phytoextraction, also called phytoaccumulation, phytoabsorption and phytosequestration. Phytoremediation involves the use of plants that are hyper-accumulators of heavy metals to remove pollutants from the environment or render them less toxic (Adewole, 2006), and it may involve degradation, extraction, dissipation and immobilization (Pivetz, 2001). It has been well documented that grasses have multiple uses in land reclamation, depending on the species and the environment (Ashbey *et al.*, 1989). In the temperate regions, scientific information are available on hyper-accumulation of Zn and Cu by *Cardiaminopsis helleri* (Newman and Zur Nieden, 2001); Cu and Ni by *Empetrum nigrum* (Monni *et al.*, 2000); Cr and Ni by *Echinocloa colona* (Rout *et al.*, 2000); Cd by several higher plants (Sanita di Toppi and Gabbrielli, 1999); and Pb by *Brassica juncea* (Blaylock *et al.*, 1997). Peralta-videa *et al.*. (2004) reported that alfalfa (*Medicago sativa*), via transplanting at 20 days after germination, effectively mop up Cd, Cu and Zn from heavy metals contaminated soils; and Obilo and Ogunyemi (2005) reported that *Zea mays* bioaccumulated Cd and Pb from crude oil-polluted soil in southeastern Nigeria.

Schnoor (2002) reported that phytoextraction is more effective with vigorously growing plants that are easily harvested and which accumulate large concentration of contaminants in harvestable form. *Tithonia diversifolia* (Hemsl.) A. Gray [mexican sunflower] is a fast growing and widely distributed invasive alien in southern Nigeria. The plant, now a weed of crop fields, waste areas and road sides, might have been introduced into West Africa as an ornamental plant (Akobundu and Agyakwa, 1998). *T. diversifolia*, as reported by Ayeni *et al.* (1997), is a dicot weed that is capable of inhabiting polluted sites. Studies of responses of *T. diversifolia* to environmental pollution in terms of growth and bioaccumulation of heavy metal pollutants are important in the search for a cheap sustainable method of cleaning up the environment and making the soils productive again. The aim of the study reported here was to ascertain if *T. diversifolia* can mop up lead and cadmium, the major pollutants in spent lubricating oil that interfere with soil agricultural productivity.

MATERIALS AND METHODS

The study was conducted in two trials, each lasting three months. The first trial and second trial was commenced on 7 March 2005 and 6 April 2005, respectively. The trials were conducted in pots in the crop garden (latitude 7°27.076^{1}N; longitude 3°53.824^{1}E; elevation 218 m asl) of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, in the rainforest-savanna transition ecological zone of Nigeria. The experiment was established in 36 pots. Each pot has 20 cm surface diameter and 22 cm depth. Pots were filled with 4 kg (dry weight) soil collected in the crop garden of the Department. The soil is sandy clay loam (59% sand, 10% silt and 31% clay), slightly acidic with pH ($CaCl_2$) 6.1 and 2.43% organic carbon. Measured volumes of spent oil, which included 0, 50, 100, 150 and 200 millilitres designated as control, low, moderate, heavy and very heavy pollution levels respectively were supplied to the pots at the commencement of the study. The experiment was conducted using a Completely Randomised Design (CRD) with three replicates. The spent oil was taken from an auto-mechanic workshop in Ibadan. The pots were left to stand for two weeks after application (WAA) of the oil to accomplish proper oil permeation of the soil. At 2 WAA two seedlings of *T. diversifolia* at 4-leaf stage were transplanted into each pot and were allowed to grow for 12 weeks.

At 4 and 7 weeks after transplanting (WAT) the following growth parameters of *T. diversifolia* were collected: stem height using meter rule, stem diameter using vernier callipers and number of leaves by visual counting. The performance of the plant in the various spent oil concentrations was compared by analysis of variance (ANOVA). Where F-test was significant, means were separated using Duncan Multiple Range Test at 5% level of probability.

Soil samples were collected at the commencement and end of each trial. Three soil samples were randomly collected per replicate and analyzed for lead (Pb) and cadmium (Cd) using Atomic Absorption Spectrophotometer. At the end of the experiment, the plants were carefully uprooted and steeped in bucket-full of water to remove the soil. The plants were separated into roots and shoots and dried in the Gallenkemp oven at 80°C to a constant weight. The dried plant parts were then milled for the analyses of lead and cadmium. All chemical analyses were done at the ROTAS Laboratory, Ibadan.

RESULTS AND DISCUSSION

Shoot growth

At 4 WAT the plant height in the control treatment of the first and second trials was 22.00±0.94 cm and 31.30±0.66 cm respectively. The plants in control treatment were significantly ($P<0.05$) taller than the plants grown in the various oil-treated soils. The heights of plants in all the oil-polluted treatments were not significantly different and did not give a specific trend (Table 1). The height in oil-polluted soil varied from 14.00±0.58 cm in 100-ml treatment to 21.60±0.0.56 cm in 50-ml treatment in Trial 1, and from 28.00±0.61 cm in 50-ml treatment to 29.00±0.56 cm in 150-ml treatment in Trial 2. The stem diameter of *T. diversifolia* in the control treatment (0.41±0.10 cm) and all the oil-polluted treatments (0.39±0.17 to 0.44±0.14 cm) were not significantly different in Trial 1. However, in Trial 2 the stem diameter in the control treatment (0.42±0.13 cm) was significantly ($P<0.05$) greater than the stem diameter in the oil-polluted soil treatments where the diameter varied from 0.30±0.12 cm in 200-ml treatment to

Table 1: Effect of spent oil on mean plant height, stem diameter and number of leaves of *Tithonia diversifolia* at 4 WAT. Values are mean±SE (n=3).

Oil Concent-ration	**Plant Height (cm/plant)**		**Stem diameter (cm/plt)**		**Number of leaves/plt**	
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
0ml	22.00±0.94a	31.30±0.66a	0.41±0.10a	0.42±0.13a	9.00±0.57a	11.00±0.60a
50ml	21.60±0.56a	28.00±0.61b	0.43±0.12a	0.35±0.10b	6.00±0.58b	9.00±0.62b
100ml	14.00±0.58d	28.30±0.63b	0.44±0.14a	0.31±0.11b	5.60±0.46b	8.70±0.47b
150 ml	15.67±0.62c	29.00±0.56b	0.42±0.12a	0.30±0.10b	5.60±0.66b	8.30±0.67b
200 ml	15.33±0.83bc	29.00±0.32b	0.39±0.17a	0.30±0.12b	5.70±0.54b	8.31±0.12b
CV (%)	12.08	19.80	1.00	0.70	9.34	8.10

Values on the same column having similar letters are not significantly different at 5% level of probability using DMRT.

Table 2: Effect of spent oil on mean plant height, stem diameter and number of leaves of *Tithonia diversifolia* at 7 WAT. Values are mean±SE (n=3).

Oil Concent-ration	Plant Height (cm/plant)		Stem diameter (cm/plt)		Number of leaves/plt	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
0ml	31.70± 0.75a	51.30±0.82a	0.59±0.12a	0.70±0.12a	16.70±0.34a	14.70±0.63a
50ml	30.00±0.97b	45.40±0.91b	0.56±0.12a	0.63±0.13b	16.00±0.54a	12.70±0.56b
100ml	30.00±1.05b	45.30±1.10b	0.56±0.10a	0.57±0.10c	13.30±068b	12.00±0.63b
150 ml	29.80±0.92b	46.30±1.20b	0.54±0.12a	0.51±0.12d	11.70±0.50c	11.30±0.54b
200 ml	30.00±0.80b	45.70±0.73b	0.53±0.10a	0.50±0.12d	11.30±0.58c	10.70±0.50b
CV (%)	19.90	16.00	0.44	0.50	32.58	27.60

Values on the same column having similar letters are not significantly different at 5% level of probability using DMRT.

0.35±0.10 cm in 50 ml treatment. In the two trials, the number of leaves decreased with increasing oil concentrations. Though all oil-polluted treatments were not significantly different in the two trials, they were significantly ($P<0.05$) less than the control (Table 1). In Trial 1 the number of leaves varied from 5.60±0.46 in 100-ml treatment to 9.00±0.57 in the control, and in Trial 2 it varied from 8.30±0.67 in 150-ml treatment to 11.00±0.60 in the control. In the two Trials, the control treatment was significantly higher than all oil-polluted treatments that were not significantly different from each other (Table 1). At this 4 WAT, the reduction in plant height, stem diameter and number of leaves, which might have been caused by the spent oil contamination of the soil varied from 2 to 36%, 16.7 to 28.6% and 18.2 to 37.8% respectively. At 7 WAT, height of *T. diversifolia* plants in the control treatment in the two trials (31.70±0.75 cm in Trial 1 and 51.30±0.82 cm in Trial 2) remained significantly ($P<0.05$) higher than all the oil-polluted treatments that were not significantly different in height (Table 2). The stem diameter in the control treatment in the two trials were higher than other treatments, but only significantly ($P<0.05$) higher in Trial 2. The number of leaves were higher in the control treatment than all oil-polluted treatments, but significantly ($P<0.05$) higher in

Table 3: Lead and Cadmium content in the experimental soil at commencement and end of the study.

Oil Concent-ration	At commencement of study				At the end of study			
	Lead (mg/kg)		Cadmium (mg/kg)		Lead (mg/kg)		Cadmium (mg/kg)	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
0ml	3.75e	3.80d	0.75d	0.70d	0.00c	0.00d	0.00c	0.00d
50ml	14.80d	15.25c	1.00c	0.95c	7.25b	4.50c	0.20b	0.18c
100ml	16.25c	19.20b	0.98c	0.98c	7.40b	5.20b	0.25b	0.17c
150 ml	18.00b	19.70b	1.50b	1.60b	7.65b	5.75b	0.25b	0.35b
200 ml	39.50a	36.00a	2.00a	2.10a	12.25a	11.50a	0.40a	0.45a
CV (%)	1.97	0.77	6.24	12.84	20.75	23.37	12.37	19.82

Values (mean) on the same column having similar letters are not significantly different at 5% level of probability using DMRT.

Table 4. Percentage reduction in lead and cadmium contents in the trial soils as a result of phytoremediation by *Tithonia* plant.

Oil	Lead		Cadmium	
Concentration	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
0-ml	100.0	100.0	100.0	100.0
50-ml	51.0	70.5	80.0	81.1
100-ml	54.5	72.9	74.5	82.7
150-ml	57.5	38.8	83.3	78.1
200-ml	69.0	68.1	80.0	78.6

Table 5. Lead and Cadmium contents in the shoot and root of *Tithonia diversifolia* at the end of the experiment (12 WAT).

Oil	**Root**				**Shoot**			
Concent-	Lead (mg/kg)		Cadmium (mg/kg)		Lead (mg/kg)		Cadmium (mg/kg)	
ration	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
0ml	2.10d	2.40e	0.50d	0.55c	0.90e	1.25d	0.20c	0.13c
50ml	5.00c	6.40d	0.60d	0.65c	2.50d	4.10c	0.25b	0.23b
100ml	6.00c	7.50c	0.70c	0.60c	3.30c	4.90c	0.26b	0.25b
150 ml	7.50b	9.90b	0.80b	0.70b	4.00b	6.75b	0.23b	0.21b
200 ml	18.70a	16.30a	1.10a	1.15a	7.00a	8.60a	0.45a	0.60a
CV (%)	15.71	3.99	9.34	12.30	15.70	3.99	8.10	9.41

Values (mean) on the same column having similar letters are not significantly different at 5% level of probability using DMRT.

Trial 2. The oil-polluted treatments were not significantly different with regards to number of leaves. At this stage, the reduction in growth caused by spent oil contamination was 5.4 to 11.7% for plant height, 5.1 to 28.6% for stem diameter and 4.2 to 32.3% for number of leaves. Other researchers have reported reduction in growth of other plants as a result of heavy metal contamination of the soil. Ogunyemi *et al.*. (2003a) reported reduction in the growth and dry matter yield of *Amaranthus cruentus* grown in heavy-metal contaminated soils collected from landfill sites in Ibadan, Nigeria. Peralta-videa *et al.*. (2004) reported 15%, 6.5% and 5.8% reduction in shoot length of alfalfa as a result of contamination of soil by cadmium, copper and zinc respectively. Waldermar and Baszynski (1996) had proven that heavy metals such as Cd(II) reduce shoot growth by reducing the chlorophyll content and the activity of photosystem I. Aside growth of plants, heavy metal contamination resulting from oil spillage may affect the flora diversity of an ecosystem. Kinako (1981) reported the deleterious effect of oil spillage on the number of plant species and productivity of a tropical grass-herb in Port-Harcourt, Nigeria. He reported that 50% of the herbaceous species such as *Aspilia africana, Chromolaena odorata* and *Emilia* species became extinct immediately after a spillage while the perennial species were less affected in the study. Clark (1992) reported the effect of oil pollution on perennials to show a wide range of reactions such that shallow rooted plants with little or no food reserve are readily killed, while others will generally survive at least a single exposure to oil. *Tithonia* was able to survive all treatments levels in this study, including the 200-ml treatment, probably due to its rapid and vigorous growth habit or because the concentrations of the heavy metals were below hazardous levels.

Heavy metal content in the Soil and Uptake by *Tithonia*

The lead and cadmium contents in the soil prior to the planting of *Tithonia* respectively varied from 3.75 mg/kg and 0.73 mg/kg in the control soil to an average of 37.75 mg/kg and 2.05 mg/kg in the 200-ml treatment (Table 3). At the end of the experiment the heavy metals could not be detected in the control soil and, in the 200-ml treatment, the contents had declined to an average of 22.06 mg/kg of lead and 0.43 mg/kg of cadmium. The percentage reduction in heavy metals in the oil-treated soils varied from 38.75% to 69% for lead and 74.5% to 83.3% for cadmium (Table 4). From the study, lead and cadmium were detected in all soil samples analyzed at the commencement of study including control samples. This suggests that alternative sources of pollution such as deposition from vehicular exhaust and domestic erosion from adjoining community might have added the heavy metals to the soil. It had been reported that particles of heavy metals contained in the car exhaust emitted into the air may be transported over several kilometres depending on emission height (Egunjobi 1989) and the particle size (Ogunyemi *et al.*, 2003b). Hana and Al-Basam (1983) reported that 25% of the vehicular emitted lead is coarse grained and deposited close to the road, while the remaining 75% is finer and may be airborne over a long distance. The contamination levels in all the treatments were below the hazardous threshold of 250 ppm for Pb and 3.0 ppm for Cd (DOE/NWC, 1981).

The lead content in the root of *T. diversifolia* was significantly ($P<0.05$) least in control treatment in the two trials (2.10 mg/kg in Trial 1 and 2.40 mg/kg in Trial 2), but increased with increasing concentrations of oil that was mixed into the soil (Table 5). The lead content in the root in 200-ml treatment was 18.70 mg/kg in Trial 1 and 16.30 mg/kg in Trial 2. Compared to the control, the lead content in the root of *T. diversifolia* in 50-ml treatment was 60.53% higher, and in 200-ml treatment the lead content was 87.14% higher. In the shoot of *Tithonia*, the lead concentration in 50-ml treatment compared to control was 67%, while in 200-ml treatment it was 86% higher. The lead content in the shoot at all treatments was about 54% of the content in the root. The cadmium content in the root of *Tithonia* varied from 0.5 mg/kg in the control to 1.15 mg/kg in 200-ml treatments. In the shoot tissue the cadmium content varied from 0.13 mg/kg in the control treatment to 0.60 mg/kg in 200-ml treatment in the two treatments (Table 3). The content in 200-ml treatment was significantly ($P<0.05$) higher than the contents in all other treatments. Compared to the control treatment, the cadmium content in the root in 50-ml treatment was 15% higher and in 200-ml treatment the content was 53% higher. However, in the shoot the cadmium content was 29% higher in 50-ml treatment and 67% higher in 200-ml treatment, compared to control. The cadmium content in the shoot at all treatments was about 30% of the content in the root. The uptake of heavy metal is corroborated by the findings of other researchers. Ogunyemi *et al.* (2003b) reported accumulation of Pb and Cd in the shoots and roots of *Amaranthus cruentus* grown in soils from landfill sites. The concentrations of these heavy metals detected in the tissues of the vegetable were higher than the optimum allowed by FAO/WHO for dietary consumption (FAO/WHO, 1978). Peralta-videa *et al.* (2004) reported an accumulation of 4650 mg of Cd/kg of root dry tissue and up to 1200 mg of Cd/kg of shoot dry tissue of alfalfa (*Medicago sativa* cv. Mesa). The complexing of heavy metals by the root-derived compounds which facilitates their uptake during plant growth may explain their extraction and accumulation in the plant tissues (Kawai *et al.*, 1988). Tukendorf *et al.* (1997) reported that the plant *Phaseolus coccineus* hyperaccumulates Cd by producing organic compounds homophylochelatins that complex Cd and convert it into non-toxic complexes. The findings by these other researchers also confirmed the higher contents of the heavy metals in the root than the shoot, which as reported by Chappelka *et al*. (1991) is attributable to the low rate of translocation of heavy metals from the roots to the shoots. The total content of the heavy metals detected in *Tithonia* plants correlated positively to their reductions in the soil contents. The regression equation relating the total heavy metal contents in *Tithonia* plant to the soil differences of the heavy metals was $y = 0.9955x + 0.0209$; $r^2 = 0.9742$ for lead and $y = 0.9137x + 0.1219$; $r^2 = 0.8581$ for cadmium, where y = soil difference of heavy metal and x = total plant contents of heavy metal.

The clean up of agricultural land by phytoremediation will have implication for the food and nutrition security of, most especially, the urban and peri-urban dwellers who consume vegetables produced at the roadside farms and wetlands within the city centres. These farm sites continue to receive the spent oil eroded from the auto-mechanic workshops. As had been shown, the vegetable produced from these sites also accumulate the heavy metals (Beavington, 1975; Ogunyemi *et al.*, 2003a; 2003b), which when taken by the unwary consumers may bioaccumulate and biomagnify in the tissues, thus causing many debilitating, intractable and life-threatening diseases (Needleman *et al.*, 1996; Chang, 1992; Ahumada, 1998).

CONCLUSIONS

The investigation elucidated that Pb and Cd are contained in all the treatment soils including the control, though at concentrations below hazardous levels. The seedlings of *T. diversifolia* tolerated the Pb and Cd at the available concentrations in the experimental soils. Accumulation of these metals in the plant only slightly reduced the growth. The content of heavy metals accumulated in the tissues of *T. diversifolia* correlated positively to the concentration of spent lubricating oil worked into the soil, and the contents were higher in the root than in the shoot. The plant is revealed by the study to be a hyperaccumulator of the two heavy metals, extracting from the soil 38.75–69% of lead and 74.5-83.3% of cadmium. Also, the contents of the heavy metals detected in the tissue of *T. diversifolia* and differences in the soil contents had high positive correlation. The study revealed that *T. diversifolia* is suitable for phytoextraction of Pb and Cd in spent oil polluted soils. However, survival of the plant and its ability to extract these heavy metals at high pollution and hazardous levels should be investigated.

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