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Full Length Research Paper

Phytoremediation potential of kenaf (*Hibiscus cannabinus L.)* grown in different soil textures and cadmium concentrations

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This study investigated effect of soil textures and cadmium (Cd) concentrations on the growth, fibre yields and Cd absorption of kenaf. Screen-house experiment was conducted in the University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria. Top soils were collected from Murtala Victoria Botanical Garden, Epe, Lagos State, Nigeria and UNAAB Teaching and Research Farm. Ten-litre plastic pots were filled with 10 kg soil. Experimental design was a 2 × 5 factorial in RCBD replicated three times. Two soil textures and five levels of Cd concentration (as Cadmium nitrate): 0, 1.5, 3.0, 4.5 and 6.0 mgCd/kg soil. Growth and yield parameters were collected. Cd content of plants and soils were determined using AAS and analyzed using descriptive statistics, ANOVA and correlation. UNAAB soil had pH of 6.3 with sandy loam texture while Epe soil had pH and texture of 5.3 and sand respectively. Control had significantly (P<0.05) higher plant height, stem girth, bast and core yields while 6.0 mg/kg had the least in the two soils. The more the concentration of Cd applied, the higher was the absorption by kenaf in the two soils. Kenaf planted in Epe soil had better absorption than UNAAB soil. There was significant (p < 0.01) positive correlation between Cd applied and Cd absorbed by kenaf.

Key words: Phytoremediation by kenaf, soil textures, cadmium concentrations.

INTRODUCTION

Cadmium (Cd) is used for wide variety of industrial, urban and agricultural applications and can be toxic to human health (Adriano, 1986; Angelone and Bini, 1992; Forstner, 1995; and Kabata-Pendias, 1992). Sources of soil contamination by Cd are the mining and smelting of Cd and Zinc (Zn), atmospheric pollution from metallurgical industries; the disposal of waste containing Cd, such as the incineration of plastic containers and batteries, sewage sludge application to land, and the burning of fossil fusel (Hutton, 1982). Plants growing in a polluted environment can accumulate the toxic metals in high concentration causing serious risk to human health when consumed (Alloway, 1995). Several studies have shown that metals such as Lead (Pb), Cd, Nickel (Ni) amongst others are responsible for certain diseases that have lethal effects on man and animals (Lawther, 1965; Giddings, 1973; Gustav, 1974).

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Conventional methods such as remediation by removing the contaminated soil from the sites, covering the contaminated area with barren soils, remediation in situ to remove contaminants and remediation by reducing bioavailability has being in practice (Gleseler, 1987). Remediation by conventional technologies is very expensive and it has been estimated that the cost of conventional remediating heavy metal-contaminated sites in the USA alone would exceed $7 billion (Salt et al., 1995). Phytoremediation has emerged as an alternative to the engineering-based methods. In this new approach, plants are used to absorb contaminants from the soil and translocate them to the shoots. The metal rich plant material may be safely harvested and removed from the site without extensive excavation, disposal cost and loss of top soil associated with traditional remediation practices (Blaylock et al., 1997). For better land restoration or remediation, plant species used for the phytoremediation process must produce sufficient biomass while accumulating high concentration of the metal in question (Chaney et al., 1997). Kenaf (*Hibiscus cannabinus L.*) grow quickly, rising to height of 1.5 to 3.5

m tall and the stem are 1 - 3 cm diameter within 3 - 4 months under sandy loam soil with 60 kgN/ha of N.P.K. (15:15:15) (I.A.R. and T, 1997). Kenaf is generally known for its bast (outer) and core (inner) fibers (Dempsey, 1975). However, it uses include fibre and food (Dempsey, 1975), medicine (Cheng, 2001), food additive (Hosomi, 2000), medium for mushroom cultivation (Cheng, 2001; Liu, 2003), environmental cleaning (Lam, 2000), oil and chemical absorbents (Sameshima, 2000). Work has been done on the phytoremediation of metal contaminated soil using kenaf (Banuelos et al., 1997) but information on the effect of soil texture and different concentrations in relation to absorption is limited and the attempt to bridge this gap formed the thrust for this work. The objective of this study was to determine effect of different soil textures and Cd concentrations on the growth, fibre yields and Cd absorption of Kenaf.

MATERIALS AND METHODS

The screen house experiment was carried out in the University of Agriculture, Abeokuta, UNAAB (Latitude 7° 9' N and longitude 30° 21' E) Ogun State, Nigeria.

Soil sampling

Top soils (0 -15 cm) were colleted from Murtala Victoria Botanical Garden, Epe (Latitude 6° 59' N and Longitude 3° 59' E), Lagos State and UNAAB Teaching and Research Farm, the two locations are in the Southwestern part of Nigeria. The soils were thoroughly mixed by a mechanical mixer and passed through 4 mm sieve to remove fibre and non soil particulate in the sample. The chemical and physical properties of the soils were determined prior to planting.

Soil preparation and planting

Ten-litre plastic pots were filled with 10kg soil that passed through a 4mm sieve. Experimental design was 2 × 5 factorial in Randomized Complete Block Design (RCBD) and replicated three times. The first factor was two soil textures and the second factor was five Cd levels (applied as Cadmium nitrate):0, 1.5, 3.0, 4.5 and 6.0 mgCd/kg soil. The soils in the pots were thoroughly mixed for even distribution of the contaminant and watered to field capacity. Three seeds of kenaf (Cuba 108) were planted and thinned to one plant per pot two weeks after germination. 60 kgN/ha of NPK (20:10:10) fertilizer was applied third week after planting and protected against insects by spraying with Nuvacron at sixth week after planting and continue at two weeks interval until 25% flowering (when harvested).

Data collection

Growth parameters such as plant height and stem girth were measured using metre rule and venier calliper respectively starting from sixth week after planting at two weeks interval until harvest. Kenaf plants were harvested by cutting it from the soil surface ninety days after planting (at 25% flowering). Plant samples were oven dried at 80° for 48 h. Bast and core yields were determined by separating the outer (bast) from the inner (core) and weighed separately. Plant samples were then blended to fine particles and sub samples were taken from each pot after sieving with 2 mm sieve for Cd determination. Soil from each pot was mixed thoroughly and sub samples were taken to know the Cd content of the soil after harvesting.

Laboratory analysis

Soil pH was determined using a glass electrode pH meter (Rent Model 720) in distilled water according to Thomas (1996). Soil organic carbon was determined by the chromic acid digestion method of Walkley and Black as reported by Sparks (1996). The total N concentration was determined by Macro-kjeldahl method according to Bremner (1996), available P was determined by Bray-I method as described by Kuo (1996). Exchangeable Ca, Mg, K and Na were extracted with neutral normal ammonium acetate buffer according to Helmke and Sparks (1996). K and Na were determined using Flame Photometer (Gallenkamp Model FH 500) and exchangeable Ca and Mg by Atomic Absorption Spectrophotometer (AAS). Cd content was determined by digesting one gram of the soil sample (<2 mm fraction) in 1:1 mixture of concentrated nitric and perchloric acids by heating the mixture plus sample over water bath in a fume cupboard. The solution was heated to dryness while the residue was re-dissolved in 5 ml of 2.0 M HCL as in Ure (1990). The mixture was finally filtered (Whatman No. 40). The resultant extracts were analyzed for Cd using AAS (APHA - AWWA - WPCF, 1980).

From each ground plant sample, 2 g was accurately weighed into clean platinum crucibles, ashed at 450°C and then cooled to room temperature in a desiccator. The ash was completely dissolved in 5 ml of 20% HCl which was then made up to volume in a 100 ml volumetric flask (Alloway, 1995). Analysis of the digest for the Cd content was carried out using the AAS. Extraction coefficient was calculated by dividing the concentration of the Cd in the shoot by that of the soil (Rotkittikhun et al., 2006). The data collected were analyzed using descriptive statistics and Analysis of Variance (ANOVA). Test of significance of the means was by the Least Significance Difference (LSD) and Duncan's Multiple Range (DMR) test. Pearson's correlation coefficient was used to determine the relationship between Cd applied / Cd absorbed and between Cd applied / residual Cd in soil after harvesting.

RESULTS AND DISCUSSION

The soils chemical and physical properties prior to planting were shown in Table 1. The pH of the UNAAB soil was 1.0 unit higher than the pH of Epe soil and it represented slightly acidic soil while Epe soil represented strongly acidic soil (Adetunji, 2005).The soils textures were sandy loam and sand for UNAAB and Epe soils respectively. The two soils were low in nutrient when compared to the nutrient ratings for soil fertility classes in Nigeria (FPDD, 1990) but UNAAB soil was more fertile than Epe soil because it had higher organic matter, total nitrogen and available phosphorous. The Cd content of the two soils was within the range (0.01 - 2.0 mg/kg) of Cd in agricultural soil (Alloway, 1995). Figures 1 and 2 and Figures 3 and 4 show the growth parameters for UNAAB and Epe soils respectively as affected by Cd concentrations from sixth week after planting (6 WAP) to twelfth week after planting (12 WAP). In the two soils, plant height and stem girth increased from 6 WAP to 12 WAP at every concentration level; and significantly

Table 1. Chemical and physical properties of UNAAB and Epe soils before planting.

Parameters	UNAAB soil	Epe soil
pH (H_2O)	6.30	5.30
Sand (g/kg)	755.00	918.00
Clay (g/kg)	75.00	11.00
Silt (g/kg)	170.00	71.00
Texture	Sandy loam	Sand
Exch. Ca ($cmolkg^{-1}$)	1.38	1.32
Exch. Mg ($cmolkg^{-1}$)	1.10	0.65
Exch. K ($cmolkg^{-1}$)	0.18	0.13
Exch. Na ($cmolkg^{-1}$)	0.12	0.85
Organic matter (g/kg)	16.30	12.20
Available P. (mg/kg)	7.50	6.20
Total N. (g/kg)	1.20	0.90
Cd (mg/kg)	0.05	0.08

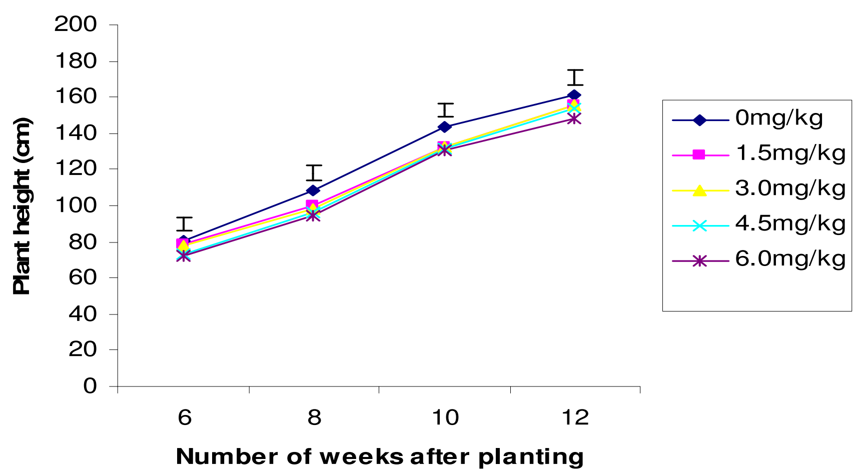

Figure 1. Plant height of kenaf as affected by cadmium concentrations in UNAAB soil.

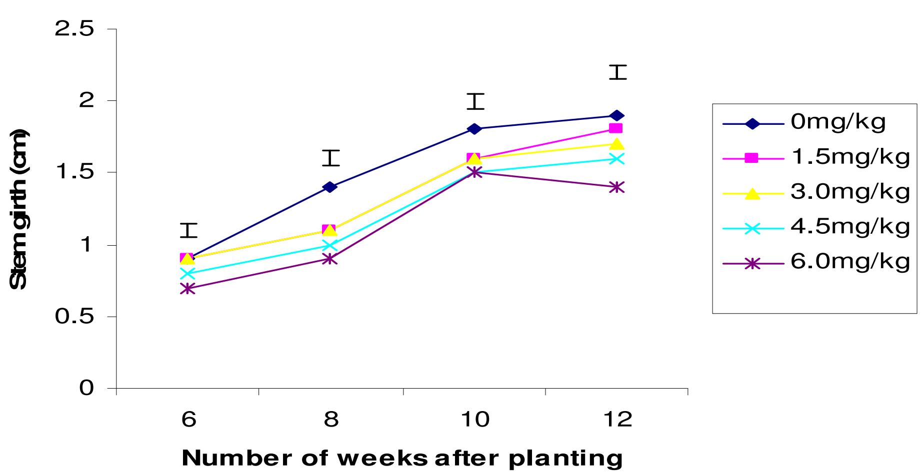

Figure 2. Stem girth of kenaf as affected by cadmium concentrations in UNAAB soil.

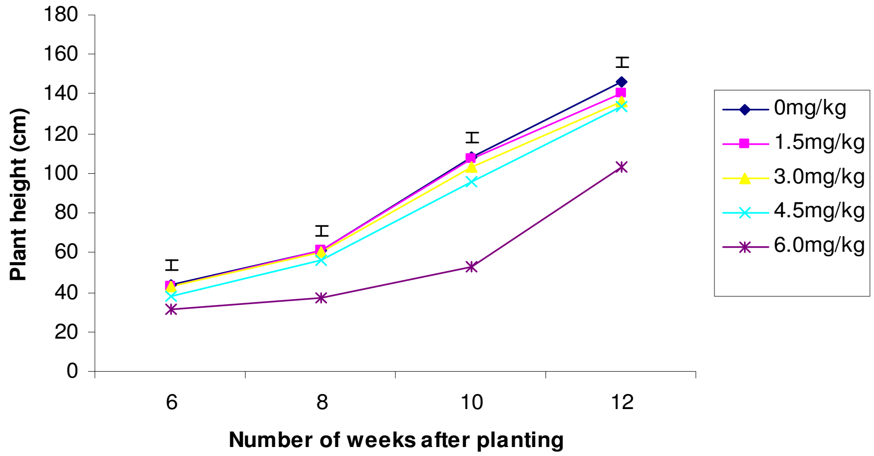

Figure 3. Plant height of kenaf as affected by cadmium concentrations in Epe soil.

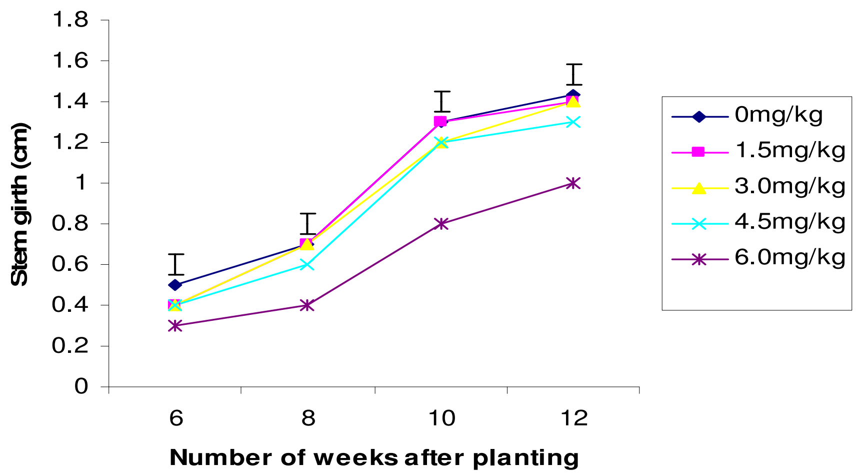

Figure 4. Stem girth of kenaf as affected by cadmium concentrations in Epe soil.

Table 2. Effect of cadmium concentrations on bast and core yields of kenaf.

Concentration (mg/kg)	UNAAB soil		Epe soil	
	Bast (g/pot)	Core (g/pot)	Bast (g/pot)	Core (g/pot)
0	11.42 ± 3.50[a]	21.20 ± 5.72[a]	7.48 ± 2.60[a]	19.12 ± 4.22[a]
1.5	9.18 ± 3.21[b]	19.22 ± 4.50[b]	5.70 ± 2.31[b]	15.30 ± 3.13[b]
3.0	8.87 ± 2.10[c]	16.12 ± 3.20[c]	4..68 ± 2.45[c]	12.40 ± 2.50[c]
4.5	8.71 ± 1.01[d]	15.10 ± 1.72[d]	4.00 ± 1.01[d]	11.35 ± 1.80[d]
6.0	7.10 ± 0.70[e]	12.20 ± 1.10[e]	3.03 ± 0.52[e]	9.50 ± 1.00[e]

Values are means ± standard deviation of three replicates. Different superscript in the same column indicates significant differences at $p < 0.05$ (DMRT).

($p < 0.05$) highest plant height and stem girth were observed in the no Cd concentration treatment (control). The bast and core yields of kenaf significantly ($p < 0.05$) reduced as concentration of Cd increased as shown in Table 2. Control had significantly ($p < 0.05$) highest bast and core yields followed by 1.5, 3.0, 4.5 and 6.0 mgCd/kg soil respectively in UNAAB and Epe soils. The reduction in bast and core yields as concentration increased might

Table 3. Effect of cadmium concentrations on cadmium absorption and bioavailability index of kenaf.

Concentration (mg/kg)	UNAAB soil		Epe soil	
	Absorption (mg/kg)	Bioavailability index	Absorption (mg/kg)	Bioavailability index
0	0.03 ± 0.02^{e}	nd	0.05 ± 0.03^{e}	nd
1.5	0.75 ± 0.21^{d}	0.50 ± 0.14^{a}	0.87 ± 0.34^{d}	0.58 ± 0.23^{a}
3.0	1.33 ± 0.32^{c}	0.44 ± 0.11^{a}	1.57 ± 0.40^{c}	0.52 ± 0.14^{a}
4.5	1.71 ± 0.38^{b}	0.38 ± 0.08^{a}	2.07 ± 0.48^{b}	0.46 ± 0.11^{a}
6.0	2.72 ± 0.42^{a}	0.45 ± 0.07^{a}	2.78 ± 0.51^{a}	0.46 ± 0.09^{a}

Nd: not determined Values are means ± standard deviation of three replicates. Different superscript in the same column indicates significant differences at $p < 0.05$ (DMRT).

Table 4. Cadmium levels of soils after harvesting

Concentration (mg/kg)	UNAAB soil Cd content (mg/kg)	Epe soil Cd content (mg/kg)
0	0.02 ± 0.01^{e}	0.02 ± 0.01^{e}
1.5	0.43 ± 0.03^{d}	0.24 ± 0.02^{d}
3.0	1.45 ± 0.15^{c}	0.62 ± 0.03^{c}
4.5	2.48 ± 0.18^{b}	1.86 ± 0.10^{b}
6.0	2.84 ± 0.31^{a}	2.83 ± 0.19^{a}

Values are means ± standard deviation of three replicates. Different superscript in the same column indicates significant differences at $p < 0.05$ (DMRT).

be due to the quantity of Cd present in the soils which is not essential for plant growth. UNAAB (sandy loam texture) soil had higher bast and core yields than Epe (sand texture) soil by 34.5 and 9.8%, respectively. The best type of soil for kenaf production is a well-drained sandy loam soil; sand soil is not recommended for kenaf production as plant growing in such soil bloom rather early, without attaining sufficient height; consequently low yields are obtained from such soil (Dempsey, 1975). The higher the concentration of Cd applied, the more was the Cd absorption by kenaf in UNAAB and Epe soils (Table 3). In the two soils, kenaf planted in 6.0 mgCd/kg soil had significantly ($p <0.05$) highest Cd absorption followed by kenaf planted in 4.5 mgCd/kg soil, 30 mgCd/kg soil, 1.5 mgCd/kgsoil and control respectively. This might probably be due to the amount of metal in the soil. Zhen-Guo et al. (2002) and Arthur et al. (2003) reported that phytoextraction and uptake of heavy metal is enhanced by its availability and concentration in the soil. Comparing the Cd absorption of kenaf planted in UNAAB and Epe soils, the kenaf in Epe soil had better absorption than the one in UNAAB soil at every concentration level. With reference to 6.0 mgCd/kg soil, kenaf planted in UNAAB soil absorbed more than the one planted in Epe soil by 2.2%.

However, bioavailability index has been used to demonstrate the ability of plants to accumulate heavy metals (Rotkittikhun et al., 2006). Epe soil also had higher bioavailability index than UNAAB soil at every concentration level (Table 3). The difference in pH (UNAAB soil 6.3 and Epe soil 5.3) and soils textures might responsible for better absorption of kenaf in Epe soil. Arthur et al. (2003) similarly observed that mobility and bioavailability of metals for plant uptake is enhanced at lower soil pH. Cd levels of UNAAB and Epe soils after harvesting decreased compared to the applied concentrations before planting (Table 4). The higher the concentration of Cd applied to the soils before planting, the more was the content in the soil after harvesting with 6.0 mgCd/kg soil had significantly ($p < 0.05$) highest level of Cd followed by 4.5 mgCd/kg soil, 3.0 mgCd/kg soil, 1.5 mgCd/kg soil and control respectively in the two soils. Pearson correlation analysis established that Cd concentration applied was positively correlated with Cd absorbed by kenaf ($r = 0.99$, $p < 0.01$ in UNAAB soil; $r = 1.00$, $p < 0.01$ in Epe soil) and with residual Cd in the soils after harvesting ($r = 0.99$, $p < 0.01$ in UNAAB soil; $r = 0.96$, $p < 0.01$ in Epe soil).

CONCLUSIONS AND RECOMMENDATIONS

Growth and yield parameters of kenaf reduced with increased in cadmium concentrations. Ability of kenaf to absorb cadmium varied with soil texture, soil pH, and concentration of cadmium in the soil. Further research could also be carried out on other varieties of kenaf at much higher concentrations of cadmium and at varying soil pH.

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