Potential of kenaf (*Hibiscus cannabinus* L.) for phytoremediation of land irrigated by waste water

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Abstract
The potential of kenaf for extraction of cadmium and zinc from polluted soil in Monastir, a town from Tunisian Sahel, was investigated. Kenaf plants were grown in a soil irrigated by sewage during 25 years. Experiment was carried out according to split plot design. Growth and yield parameters were collected. Cd and Zn content of plants and soil were determined using anatomic absorption spectrophometry. The translocation and bioconcentration factor were used to evaluate potential of kenaf to remove trace metals from soil. Quantities of trace metals extracted showed that decontamination of Zn and Cd polluted substrates is possible by kenaf crop. Tolerance and bioaccumulation factor indicated that kenaf could be used in phytoextraction.

Introduction

Problems with contaminated soils are more and more preoccupying. Among the contaminants generated by urban activity and agri-cultural practices, the most common are trace metals. The sources of trace metals in arable lands include natural source, mining, agrochemicals and sewage sludge applications. Sewage irrigation can alleviate the water shortage to some extent, but it can also bring some toxic heavy metals, to agricultural soils, and cause serious environmental problems. Remediation of trace metals polluted soil could be carried out using physico-chemical processes. However, these techniques disrupt the biological activity and require special high cost equipments. Phytoextration has emerged as an approach to clean up metal polluted soils in which plants are used to extract toxic metals from soils. For rapid land remediation, plant species used for phytoextraction process must produce sufficient biomass while accumulating high concentration of metals. Kenaf (Hibiscus cannabinus L.), an annual herbaceous plant from the Malvacea family, was selected for this study. Kenaf is suite for use in building materials, textiles and absorbents [11]. Kenaf is also makes good animal forage with high crude protein in leaves [12]. In the present study, the potential of kenaf for extraction of cadmium and zinc from polluted soil was investigated.

Material and Methods

Plant material

Plants of Kenaf, cultivar Tuning 2 were obtained by seeding. Sowing was done on April 1 in dimpled plates on brown peat. Planting in the experimental plot was made May 2.

Experimental site and treatments

The experiment was conducted in field in two plots of the golf course Monastir. The first has never been irrigated with treated wastewater (NC) and the second was continuously irrigated for 20 years wastewater in Monastir, a town from Tunisian Sahel.

Four treatments were performed. In both plots, the plants developed were either irrigated throughout culture period or potable water (PW) or treated wastewater (WW). The four treatments are:
- NCPW(Control): uncontaminated soil (NC) irrigated with potable water (PW).
- NCWW: uncontaminated soil (NC) irrigated with wastewater (WW).
- CPW: Contaminated soil (C) irrigated with potable water (PW).
- CWW: Contaminated soil (C) irrigated with wastewater (WW).

Plant and substratum analysis

Physico-chemical properties of soil were determined before experiment. Total N content was determined using the Kjeldahl method (ISO11261: 1995). Total P content was determined using the molybdenum blue method and molecular absorption spectrophotometry after sediment digestion using aqua regia composed of HCl and HNO3 (NFEN ISO 6878:2005). The total content of Ca, Mg, Na, K and metal trace elements (As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn) (after aqua regia digestion) and the percentage of available metals (extraction with 0.5 N NH4OAc, 0.5 N HOAc, 0.02 MEDTA, pH 4.65) were measured using the atomical absorption spectrometry (AAS800- PerkinElmer) (ISO 11 466:1995, NBN EN 13657:2002, ISO 11407:1998, ISO 20280:2007). The amount of Co3 adsorbed was then measured by inductively coupled plasma spectrometry (ICP). Levels of organic carbon were determined using the sulfochromic oxidation method (ISO 14 235:1998). Cation exchange capacity of the substrate was determined by saturation with a cobalt hexamine chloride solution [Co(NH3)6Cl3] (NFX31-130).

Plant uptake and translocation

In order to evaluate plant's phytoextraction efficiency, the bioaccumulation factor (BCF) and the transfer factor (TF) and amount metal extracted were calculated as following:

BCF = C_{shoot} (mg/kg) / C_{soil} (mg/kg)

TF = C_{shoot} (mg/kg) / C_{root} (mg/kg)

Where, C_{shoot} and C_{root} are respectively, the concentration of metal in shoot and root. C_{soil} is the concentration of total concentration of metal in soil.

Statistical analysis

Experimental data were subjected to one way analysis of variance using the SAS package with the least Significance Difference (LSD) test. Differences were considered significant at $p<0.05$.

Results

Effects of treatments on growth productivity and biomass quality of kenaf plants

Plant's growth does not vary depending on the site of cultivation or as a function of the quality of the irrigation water used (Table 1. All growth parameters observed namely plant height, stem diameter measured at a height of 2 cm from the collar and the dry part of the root meristem and the party have no significant difference (Table 1). These observations show the indifference of this plant to treated wastewater. Indeed, these results confirm those of Arbaoui and Ben Salah (2011) Who observed a similar behavior of Kenaf irrigated with waste water and even talk of a positive effect, estimated at 7%, compared to crops grown with water lightly loaded salt having an electrical conductivity of 1.45 dS / m.

Table 1. Growth parameters and biomass quality of kenaf plants

Treatments	Hauteur (cm)	Diameter (mm)	Total dry matter (g/plant)	Shoot dry matter (g/plant)	Root dry matter (g/plant)
1	125.34±3.51	14.76±1.62	54.16±2.12	47.22±1.52	7.38±0.83
2	128.56±2.62	15.32±1.43	55.18±1.81	48.15±1.71	7.03±0.74
3	124.78±3.77	14.45±1.34	53.45±2.36	46.31±1.83	7.14±1.12
4	126.45±2.45	16.23±1.32	56.04±2.48	48.12±1.74	7.92±0.71

Zinc and cadmium uptake by kenaf and bioaccumulation factor

Cd and Zn initial levels in soil (3.54 mg/kg of Cd and 1157 mg/kg of Zn) decreased after cultivation of kenaf. Cd and Zn concentrations decreased gradually in root, stem and leaf (Table 2).

Despite high concentrations of Cd in roots no visual symptoms toxicity were observed indicating that kenaf is a Cd tolerate species . Results confirmed by Baji and Raji [3] whose reported that ability of kenaf to absorb Cd varied with soil texture, soil pH and Cd concentration in soil.

The ability of kenaf to accumulate Cd and Zn was reported by Nabulo et *al*. [9] comparing 14 tropical species according to the accumulation of five trace metals. kenaf was ranked second after *Gynandropsis gynandra* L.

The BCF is a key index used to evaluate accumulation efficiency in plants. The transfer factor (TF) (Table 3) determined for *H. cannabinus* tissues showed a potential of kenaf for cadmium extraction. Generally, in all treatments, TF values obtained for the above and underground part of the plants were important. Therefore, cadmium and zinc was accumulated in greater concentrations in plant roots.
On the other hand, the Bioconcentration Factor (BCF) average in tissues of kenaf, being the roots more effective than shoots in accumulating Cd and Zn.

Table 2. Metal concentration in plants after three months of cultivation

Treatment		Zn (mg/kg)	Cd (mg/kg)
CWW	Root	65.33 ± 4.45	2.67 ± 0.41
	Stem	53.90 ± 1.74	1.74 ± 0.22
	Leave	21.62 ±1.05	0.37 ± 0.07
CPW	Root	60.98 ± 1.55	1.95 ± 0.32
	Stem	54.55 ± 3.17	1.06 ± 0.15
	Leave	22.09 ± 0.72	0.43 ± 0.03
NCWW	Root	60.49 ± 6.44	0.31 ±0.02
	Stem	47.84 ± 0.25	0.25 ± 0.10
	Leave	25.30 ± 4.08	0.0013 ± 0.006
NCPW	Root	50.57 ± 2.24	0.22 ± 0.09
	Stem	35.00 ± 3.57	0.007 ± 0.006
	Leave	21.85 ± 2.25	0.007± 0.005

Table 3. Bioaccumulation and transfer factors

Treatment	Zn		Cd	
	BCF	TF	BCF	TF
CWW	56.46 10^{-3}	0.330	0.754	0.138
CPW	52.70 10^{-3}	0.362	0.550	0.220
NCWW	52.28 10^{-3}	0.418	0.080	0.041
NCPW	43.70 10^{-3}	0.431	0.060	0.031

The effectiveness of phytorextraction is primarily dependent on the choice of plant species that are not only tolerant but also able to accumulate trace metals in their tissues. The uptake and translocation of trace metal in plants vary greatly, not only among plant species but also among cultivars within the same species [6]. Hinestly et *al* [7] reported a variation in the concentration of Cd among cultivars of corn. Difference in phytoextraction potential among varieties of kenaf was reported by Cartoga et *al* [5] in a study comparing 5 varieties of *H.cannabinus L* (Tainung 2, Everglades 41, Gregg, Dowling, SF 459 and G4) grown in soil contaminated with trace elements. Tainung 2 accumulates more Cd in shoot than others varieties, while Everglades 41 has the highest concentration of Zn in shoot.
No visible symptoms of toxicity were observed during the culture. Kenaf can be cultivated in contaminated soil. A study conducted by Santos et *al*. [10] in a greenhouse showed that kenaf grown in a pot containing-naturally contaminated soil tolerates 104 mg/kg of Pb and 10 mg/kg of Cd.

Conclusion and perspectives

We evaluated the potential of Kenaf for phytormediation of soil contaminated by sewage sludge and contains trace metals. Kenaf can be used in a phytoremediantion process of contaminated substrates in particular with cadmium thus reducing the risks resulting from the presence of trace metals in these substrates. However, remediation process in long. Kenaf have high tolerance to low soil fertility and does not require much field management. So, it can be cultivated in order to improve the ecological as well as economic values of marginal lands and for energy production, trace metals accumulated in shoots will remain on the ashes. This represents an input to the economical value for a sustainable agriculture strategy.

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