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ABILITY OF BOTH *Cupressus sempervirens* L. AND *Eucalyptus camaldulensis* DEHN. TO REMEDIATE CADMIUM-CONTAMINATED SOIL UNDER NITROGEN FERTILIZATION

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ABSTRACT

A pot experiment was conducted from March 2003 to October 2004 at the greenhouse of Sabahia Horticultural Research Station in Alexandria, Egypt to ascertain the ability of both cypress (*Cupressus sempervirens* L.) and red gum (*Eucalyptus camaldulensis* Dehn.) seedlings to remediate cadmium-contaminated soil. Three different Cd^{2+}levels as cadmium chloride (0, 30 and 60 mg kg $soil^{-1}$) and 2 rates of nitrogen as $(NH_4)_2$ SO_4 (0 and 300 mg kg $soil^{-1}$) were combined in six treatments and added to the soil of the seedlings. Height, diameter, leaves number, biomass and the uptake of cadmium in roots, stem and leaves were determined for the two species. Elsewhere, correlations between the cadmium content in leaves and roots of both species and the cadmium contamination in the soil were determined.

The cadmium content of soils of both cypress and red gum seedlings were not differed significantly although the red gum soils had low concentrations of cadmium than the soils of cypress. Addition of nitrogen dose with the low rate of cadmium (30 ppm) reduced the cadmium concentration in the soil by 29% likewise, the same dose of nitrogen combined with 60 ppm of cadmium reduced the metal concentration in the soil by about 46%.

This study revealed that cadmium treatments had no effect on leaf number where had little significant effects in reducing the height growth of both species. On the other hand, the diameter growth was increased in the high cadmium concentration of 60 ppm without nitrogen with comparing to other treatments. When nitrogen was added to the same dose of cadmium the diameter growth greatly reduced. Increasing cadmium treatments from 30 to 60 ppm consequently, had increased the fresh and dry mass of leaves and stems whereas the roots biomass increased only by the high concentration of cadmium. Furthermore, nitrogen accompanied with the cadmium levels increased the fresh and dry weights of both species. For the two species of trees, the highest cadmium level treatment the highest uptake by plants. The results of this study proved that, red gum (*Eucalyptus camaldulensis* Dehn.) is an efficient tree to remediate the Cd-contaminated soils as well as under this condition, fertilizing the seedlings by nitrogen is surely improve its efficiency to uptake this pollutant.

INTRODUCTION

Cadmium (Cd^{2+}), a heavy metal, has no biological function and is highly toxic to plants and animals. It is taken up by plants and may accumulated in harvested parts of agricultural crops to unacceptable levels, causing health risks, reduction of crop yields and toxic effects on soil microorganisms. Whereas the maximum tolerable intake of Cd^{2+} for humans, recommended by FAO and WHO is 70 µg/day, cadmium pollution is of increasing scientific interest since it is readily taken up by the roots of many plants species and its toxicity is generally considered to be 2–20 times higher than that of other heavy metals (Jagodin *at al.*, 1995). The main sources of Cd^{2+} pollution are metal mining, manufacture and disposal as well as some agricultural practices as applying of Cd-containing phosphate fertilizers, sewage sludge and pesticides

Phytoremediation or phytoextraction is a new technology uses plants and trees to remove soil pollutants by acting as filters or traps (Black, 1995). Phytoextraction is based on root uptake of these pollutants and storage them in the plant as less toxic compounds. Compared with other remediation technologies, phytoremediation is less expensive (1000-fold less expensive than excavation and reburial of soil (Cunningham and Ow, 1996). The use of phytoremediation is restricted to low and moderate levels of contamination. Trees are ideal remediators as they are fast growing perennials with extensive root systems and high transpirational rates (Pullman *et al.*, 1998). Their large biomass is advantageous since it permits higher tolerance for toxic materials and has the capacity for accumulating contaminants. Certain trees called hyperaccumulators, can survive in contaminated soil and are able to accumulate large amounts of heavy metals in their roots and or accumulate them in aerial parts (Grant *et al.*, 1998). The amount of Cd^{2+} accumulated and translocated in plants varies with species however for instance, *Salix sp., Populus sp.* as well as *Acacia saligna, Casuarina equisetifolia*and *Cupressus sempervirens* trees show strong ability to accumulate cadmium (Taha, 2002; Sottnikova *et al.*, 2003 and Walter *et al.*, 2003). Such plants possess a range of potential cellular mechanisms that may be involved in the detoxification of heavy metals and thus tolerance to metal stress. These include binding the metal to cell wall and extracellular exudates, reduced uptake or efflux pumping of metals at the plasma membrane, chelation of metals in the cytosol by peptides such as phytochelatins, the repair of stress-damaged proteins; and the compartmentation of metals in the vacuole by tonoplast-located transporters (Hall, 2002).

Previous studies suggested that the phytoextraction process is enhanced when metal availability to plant roots is facilitated through the addition of acidifying agents to the soil (Blaylock and Huang, 2000).

Cieslinski *et al.*, (1998) and Pankovic *et al.*, (2000) concluded that the release of low-molecular-weight organic acids exudates by the plant modifies the flow and availability of plant nutrients as well as toxic metals such as Cd^{2+} by acidification, chelation and precipitation reactions, whereby the soil rhizosphere in relation to Cd^{2+} specification and availability plays an important role. Also, it is known that Cd^{2+} is taken up via a carrier-mediated system (Mullins and Sommers, 1986).

The objective of this study was to determine the ability of *Cupressus sempervirens* and *Eucalyptus camaldulensis* to remediate the contaminated soil with different rates of cadmium where nitrogen dose was added as an assistant agent.

MATERIALS AND METHODS

A greenhouse experiment was conducted at Sabahia Horticultural Research Station in Alexandria, Egypt from March 2003 till October 2004. One-year-old seedlings of cypress (*Cupressus sempervirens* L. family: Cupressaceae) and red gum (*Eucalyptus camaldulensis* Dehn. family: Myrtaceae) were transplanted into large plastic bags, 30 cm in dim., filled with 6 kg of silty clay soil (with 21.9 % $CaCO_3$, EC, 4.9 dS m^{-1}, 1.2 % organic matter and pH, 8.0). The physical soil structure was 19.0 % sand, 40.2 % clay and 40.8 % silt. The chemical characteristics of the soil were determined in Table (1) according to Jackson (1967). Seventy two seedlings for each species were arranged in 4 blocks as a factorial randomized complete block design with two factors. Three levels of cadmium as $CdCl_2$ (0, 30 and 60 mg kg^{-1} soil) and 2 rates of nitrogen as $(NH_4)_2SO_4$ (0 and 300 mg kg^{-1} soil) were combined in 6 treatments as the first factor and the two seedling species were the second one. Both cadmium chloride and ammonium sulphate levels were divided into 2 equal doses and added to the soil throughout April 2003 and October 2003. The seedlings were irrigated every other day during summer season and once every four days during winter.

Table (1): Chemical analysis of the planting soil at beginning of the study.

Parameters		Mean
Ca^{++}	Soluble cations mg/ L	54.0
Mg^{++}		82.0
K^{+}		96.0
Na^{+}		41.0
$SO^{=}_4$	Soluble anions mg/ L	0.08
HCO^{-}_3		0.002
Cl^{-}		0.06
N	Macro-element p.p.m.	41.0
P		4.7
Cd	Micro-element p.p.m.	0.24
Zn		6.2
Cu		8.5
Fe		4.9

Height and diameter growth, leaves number and biomass of leaves, stem and roots were measured on October 2004 for the two species. Soil was carefully washed out so that the root systems became free of the supporting medium. Plant material was wet digested by acid mixture (Chapman and Paratt, 1961) then cadmium concentrations in the three plant parts were determined by Atomic Absorption Spectroscopy (AAS).

The soil paste extract was used to determine the soluble cations and anaions as described by Rhoades (1982). Nitrogen was extracted and determined by Kjeldahl method (Page *et al.*,1982) where phosphorus was extracted using sodium bicarbonate according to Olsen *et al.* (1954) and measured colorimetrically using ammonium molybdate and stannous chloride as a reducing agent (Jackson,1967). Potassium was extracted by

1.0 N ammonium acetate and determined photometrically using flame photometer according to Knudsen *et al.* (1982). The soil cadmium was extracted by DTPA (0.005M DTPA in 0.01M $CaCl_2$ and 0.1M triethanol amine) according to Lindsay and Norvell (1978) and was measured by the Atomic Absorption Spectroscopy (AAS).

Statistically significant differences among means were identified using analysis of variance (ANOVA) for a randomized complete block design. Also, correlations between the cadmium content in leaves, stem and roots of both species and the cadmium level in the soil were determined. Means were separated using Duncan's Multiple Range Test at $p < 0.05$ using SAS procedures (SAS, 1985) and only main effect of means were reported.

RESULTS AND DISCUSSION

Cadmium content in the soil

The effects of the different cadmium treatments, after 20 months, applied to the soil of both cypress and red gum seedlings are shown in Table (2). The data illustrated that the metal concentrations in the soil of both control treatments (T1) were reduced by 33% due to the seedlings growth compared with unplanted soil whereas, adding nitrogen dose of 300 ppm increased this reduction to 50%.

The relatively high cadmium concentration was 10.66 ppm that found in (T5) soil which contaminated by the higher rate of cadmium. This concentration was 1.5-fold higher than (T3) soil that contaminated by the low rate of cadmium (Table 2). Overall cadmium and nitrogen treatments, means of cadmium content in soils of both cypress and red gum seedlings were not differed significantly although the red gum soils had low concentrations of cadmium (4.30 ppm) than the soils of cypress (5.22 ppm) therefore, they have the same ability as cadmium excluders.

Addition of nitrogen dose with the low rate of cadmium (30 ppm) in (T4) reduced the cadmium concentration in the soil by 29% compared with (T3). Likewise, the same dose of nitrogen combined with 60 ppm of cadmium (T6) reduced the metal concentration in the soil by about 46% in comparing with (T5).

Table (2): Available cadmium (ppm) of the soil of both cypress and red gum seedlings at the end of experiment

Treatments (Cd + N)	Cadmium (ppm) Cypress	Red gum	Mean
T1 (0+0)	0.17	0.15	0.16c
T2 (0 + 300)	0.14	0.10	0.12c
T3 (30 + 0)	7.87	6.08	6.98ab
T4 (30 + 300)	6.64	5.14	4.95bc
T5 (60 + 0)	11.13	10.19	10.66a
T6 (60 + 300)	9.36	8.80	5.72ab
Mean	5.22x	4.30x	

Means followed by a similar letter within a column (a, b) or row (x, y) are not significantly different at the probability level 0.05 using Duncan's Multiple Range Test.

These results are confirmed by Walter *et al.*, (2003) in soils of *Betula, Salix, Fraxinus and Sorbus* trees. The high values of cadmium found in the soils of (T5 and T6) is probably due to either the boundary growth of the seedlings in the pot that limited the distribution of the roots, or the high dose of cadmium applied to these treatments. Moreover, Norvell and Garrett, (2001) stated that the main soil factors that appear to influence cadmium availability are the total amount of cadmium, the nature of the soil solid phases that bind cadmium (e.g., clays, carbonates) and the soil pH. In addition, Lindsay, (1979), concluded that formation of chloro-complexes of cadmium should become significant when Cl^- concentrations rise above approximately 10 m*M*. Formation of complexes with Cl^- tends to shift cadmium from the solid to the solution phase, thereby enhancing solubility and mobility, as well as, increasing transport to roots, these chloro-complexes of cadmium may also be taken up directly by plant roots, but through mechanisms different than those responsible for uptake of unassociated cadmium (Smolders *et al.*, 1998).

Growth characteristics

Table (3) illustrated that all cadmium treatments had little significant effects in reducing the height growth of both species consequently, all treatments and control had the same significance and minimizing the seedling's height compared with the nitrogen treatment (T2) that gave 203.21cm.

Table (3): Effect of different cadmium and nitrogen treatments on the vegetative growth of both cypress and red gum seedlings after 20 months from transplanting.

Treatments (Cd + N)	Height (cm)		Mean	Diameter (cm)		Mean	Leaf number		Mean
	Cypress	Red gum		Cypress	Red gum		Cypress	Red gum	
T1 (0+0)	96.88	169.00	132.94b	0.73	0.89	0.81bc	35.10	[illegible]	155.93a
T2 (0 + 300)	109.33	297.08	203.21a	0.63	1.28	1.11ab	23.03	332.00	177.52a
T3 (30 + 0)	98.98	130.13	114.56b	0.67	0.89	0.78c	31.65	264.50	148.08a
T4 (30 + 300)	113.50	155.53	134.52b	0.61	1.44	1.03abc	30.50	280.94	155.73a
T5 (60 + 0)	114.33	193.75	154.04b	0.71	1.77	1.24a	37.10	256.00	146.55a
T6 (60 + 300)	124.33	173.65	148.99b	0.82	1.00	0.91bc	45.53	275.00	160.27a
Mean	109.55y	186.52x		0.70y	1.21x		33.82y	264.20x	

Means followed by a similar letter within a column (a, b) or row (x, y) are not significantly different at the probability level 0.05 using Duncan's Multiple Range Test.

On the other hand, the diameter growth was increased in the soil contaminated by 60 ppm of cadmium without nitrogen (T5) with comparing to other treatments. When nitrogen was added to the same dose of cadmium (T6), the diameter growth greatly reduced, that statistically was equivalent with control treatment and the thinner diameter obtained from (T3) that gave 0.78 cm only. Although a clear effect of cadmium on seedling growth was observed, the leaf number was not altered significantly (Table 3).

Generally, the red gum tolerated the different cadmium treatments than cypress seedlings therefore, they donate the best height and diameter growth (186.52 and 1.21 cm, respectively) as well as the huge leaves number (264.20).

It is shown in (Table 3) that nitrogen addition with cadmium in (T4 and T6) decreased the inhibitory effects of cadmium on height growth of both species. This result is compatible with that of Grant and Bailey, (1998) on grain and Pankovic *et al.*, (2000) on sunflower, that optimal nitrogen nutrition decreases the inhibitory effects of cadmium. This may be due to that cadmium affected the ribulose-1,5-bisphosphate (RuBP) regeneration capacity of the Calvin cycle more than other processes. At the same time, the amounts of soluble and ribulose-1,5-bisphosphate carboxylase/ oxygenase (Rubisco) protein increased with cadmium treatment (Pankovic *et al.*, 2000).

Biomass

Tables (4- a, b, c) revealed that the negative effect of cadmium on growth characteristics was accompanied by an increase in biomass of both species comparing with control treatment.

Leaves biomass: Increasing cadmium treatments from 30 ppm (T 3) to 60 ppm (T5) consequently, had increased the fresh and dry mass of leaves from 164.85 and 35.15 g seedling^{-1} to 209.78 and 53.40 g seedling^{-1} respectively (Table 4-a). Furthermore, nitrogen accompanied with the cadmium levels increased the leaves fresh and dry weights of both species whereas (T 4) produced 182.09 and 44.06 g seedling^{-1} respectively and (T 6) recorded the highest fresh and dry mass (219.61 and 61.65 g seedling^{-1} respectively) comparing with the others.

Stem biomass: The stem biomass had the same trend of leaves mass (Table 4-b) therefore, the cadmium treatments without nitrogen (T 3 and T 5) produced 348.33 and 511.57 g seedling^{-1} of fresh weight respectively that were higher than control and (T 2) treatments. Although, addition of nitrogen to the highest cadmium level (T 6) had increased both fresh and dry mass of the stem compared with (T 5), but it was not significantly. Similar trend was obtained in fresh weight from applying nitrogen plus 30 ppm of cadmium treatment (T 4) that was not significant with (T 3) while it was significant for dry weight.

Table (4-a): Effect of different cadmium and nitrogen treatments on the leaves biomass of both cypress and red gum seedlings after 20 months from transplanting.

Treatments (Cd + N)	Leaves F.W. (g seedling^{-1})		Mean	Leaves D.W. (g seedling^{-1})		Mean
	cypress	red gum		Cypress	Red gum	
T1 (0+0)	61.94	202.03	131.99f	27.09	46.50	36.79d
T2 (0 + 300)	62.59	256.50	159.55e	25.31	49.26	37.28d
T3 (30 + 0)	83.99	245.70	164.85d	21.67	48.63	35.15d
T4 (30 + 300)	85.86	278.32	182.09c	28.17	59.94	44.06c
T5 (60 + 0)	92.05	327.50	209.78b	33.75	73.04	53.40b
T6 (60 + 300)	102.71	336.50	219.61a	46.87	76.43	61.65a
Mean	81.52y	274.43x		30.48y	58.97x	

Means followed by a similar letter within a column (a, b) or row (x, y) are not significantly different at the probability level 0.05 using Duncan's Multiple Range Test.

Roots biomass: Table (4-c) showed that the higher cadmium treatments with and without nitrogen (T6 and T5) were statistically similar since they gave the greatest fresh mass (150.83 and 168.03 g seedling^{-1}, respectively) as well as dry mass (56.68 and 57.86 g seedling^{-1}, respectively) of roots. On the other hand, the remaining treatments were statistically similar for fresh and dry weights of roots of both species.

Table (4-b): Effect of different cadmium and nitrogen treatments on the stem biomass of both cypress and red gum seedlings after 20 months from transplanting.

Treatments (Cd + N)	Stem F.W. (g seedling^{-1})		Mean	Stem D.W. (g seedling^{-1})		Mean
	Cypress	Red gum		Cypress	Red gum	
T1 (0+0)	36.85	326.60	181.73c	10.85	149.76	80.30e
T2 (0 + 300)	53.10	453.75	253.43c	22.2	171.87	97.04d
T3 (30 + 0)	38.45	65.8.20	348.33b	11.45	269.79	140.62c
T4 (30 + 300)	44.25	726.27	385.26b	20.15	313.46	166.81b
T5 (60 + 0)	90.05	933.08	511.57a	33.65	385.30	209.47a
T6 (60 + 300)	69.95	995.65	532.80a	24.9	398.81	211.86a
Mean	55.44y	682.26x		20.53y	281.50x	

Means followed by a similar letter within a column (a, b) or row (x, y) are not significantly different at the probability level 0.05 using Duncan's Multiple Range Test.

Table (4-c): Effect of different cadmium and nitrogen treatments on the roots biomass of both cypress and red gum seedlings after 20 months from transplanting.

Treatments (Cd + N)	Roots F.W. (g seedling^{-1})		Mean	Roots D.W. (g seedling^{-1})		Mean
	Cypress	Red gum		Cypress	Red gum	
T1 (0+0)	24.75	59.35	42.05b	8.30	23.13	15.71b
T2 (0 + 300)	31.95	54.10	43.03b	9.80	24.00	16.90b
T3 (30 + 0)	23.80	140.10	81.95b	8.50	54.4[illegible]	31.45b
T4 (30 + 300)	27.10	73.13	50.11b	9.65	29.73	19.69b
T5 (60 + 0)	36.05	300.00	168.03a	13.25	102.46	57.86a
T6 (60 + 300)	29.35	272.32	150.83a	11.50	101.85	56.68a
Mean	28.83y	149.83x		10.17y	55.93x	

Means followed by a similar letter within a column (a, b) or row (x, y) are not significantly different at the probability level 0.05 using Duncan's Multiple Range Test.

Tables (4-a, b, c) illustrate that the red gum seedlings produced the highest fresh mass (274.43, 682.26 and 149.83 g seedling^{-1}) as well as the greatest dry weight (58.97, 281.50 and 55.93 g seedling^{-1}) of leaves, stems and roots, respectively comparing with cypress seedlings that recorded 81.52, 55.44 and 28.83 g seedling^{-1} of fresh mass and 30.48, 20.53 and 10.17 g seedling^{-1} of dry mass of leaves, stem and roots, respectively.

The disadvantage of cypress species that it is a slow growing tree consequently, it has a small biomass that serves to limit their range of phytoextraction effectiveness rather than the red gum species that produce abundant biomass. The results of this study on biomass supports the view of

Abouelkhair and Elsokkary, (1988) for the fresh weights of *Casuarina gluca* and Moya *et al.*, (1993) and Smykalova and Zamecnikova (2003) who found that Cd- treated seedlings increased the dry mass and DW/FW ratio. Also, Taha, (2002) concluded that the application of Cd generally increased the growth of *Acacia saligna, Casuarina equisetifolia and Cupressus sempervirens* trees.

Cadmium uptak

After 20 months, the cadmium uptake ranged from 0.356 to 13.302 ppm in whole plant of red gum and from 0.054 to 1.612 ppm in cypress seedlings (Table 5). For the two species of trees, the highest cadmium level treatment the highest uptake by plants where they ranked as (T6)> (T4)> (T2). Roots of cypress seedlings grown in cadmium- treated soils were significantly richer in this heavy metal that captured 72.7% of cadmium more than those of the red gum after 20 months. Moreover, cadmium translocation to stem was greater in (T6) than in the rest treatments that accumulated 3.577 ppm while the translocated cadmium through stem of red gum seedlings was 15- fold of that through tem of cypress seedlings. Similar results were obtained for the leaves where (T6) had the highest value of cadmium (8.989 ppm) compared with the other treatments. Likewise, the leaves of red gum accumulated more cadmium compared with the leaves of cypress that captured 8.817 and 0.207 ppm respectively.

In the whole plant, addition of nitrogen to cadmium treatments enhanced the uptake of cadmium in the three plant parts (Table 5). Also combining nitrogen with cadmium in (T4) and (T6) treatments increased the root uptake of the metal from the soil that absorbed 3.941 and 7.457 ppm of cadmium where in stem, combined nitrogen with the higher cadmium level (T6) only resulted in the highest rise of this element in the stems that uptake 3.577 ppm of cadmium while in (T4) addition of nitrogen decreased the cadmium uptaked. The leaves of the seedlings grown in the soil contaminated with 60 ppm of cadmium combined with nitrogen (T6) had the highest accumulation of cadmium that captured 8.989 ppm comparing with the treatment of 60 ppm only (T5). Subsequently combining nitrogen with 30 ppm of cadmium (T4) had the same trend when compared with the treatment 30 ppm of cadmium only (T3). This agrees with the results reported by (Grant and Bailey, 1998) who investigated the effects of nitrogen application on cadmium concentration of the grain of durum wheat. Cadmium accumulation increased substantially with N application. Otherwise, the sulphate molecule of $(NH_4)_2SO_4$ fertilizer that added to the seedlings, may increased cadmium availability according to (Salardini *et al.*, 1993).

The maximum accumulation of cadmium in cypress plants occurred in roots followed by stems and leaves that represented 49, 26 and 25% of the total accumulation. Contrary among the red gum parts, the higher cadmium accumulation occurred in leaves followed by stems then roots where represented 71, 27 and 2% (Fig. 1). The result of increasing cadmium accumulation in roots of cypress more than leaves and stems was similar with that of Abouelkhair and Elsokkary, (1988); Banko *et al.*, (2002); Taha, (2002) and Smykalova and Zamecnikova (2003) on different kinds of trees, shrubs and perennials.

Table (5): Effect of different cadmium and nitrogen treatments on the cadmium uptake of leaves, stem and roots of both cypress and red gum seedlings after 20 months from transplanting.

Treatments (Cd + N)	Cadmium uptake (p.p.m.)											
	Roots			Stem			Leaves			Whole plant		
	Cypress	Red gum	Mean	Cypress	Red gum	Mean	Cypress	Red gum	Mean	Cypress	Red gum	Mean
T1 (0+0)	0.000	0.042	0.021f	0.054	0.15	0.102f	0.000	0.493	0.247f	0.054	0.356	0.205e
T2 (0 + 300)	0.024	0.059	0.042e	0.266	0.344	0.305e	0.051	0.93	0.491e	0.307	0.713	0.510e
T3 (30 + 0)	0.268	0.102	0.185d	0.137	3.507	1.822c	0.108	9.057	4.583d	0.441	6.628	3.535d
T4 (30 + 300)	0.544	0.239	0.392c	0.242	3.135	1.689d	0.225	10.942	5.584c	0.861	7.021	3.941c
T5 (60 + 0)	0.562	0.568	0.565b	0.236	5.78	3.008b	0.203	14.158	7.181b	0.866	11.067	5.967b
T6 (60 + 300)	1.019	0.748	0.884a	0.374	6.78	3.577a	0.656	17.322	8.989a	1.612	13.302	7.457a
Mean	0.403x	0.293y		0.218y	3.283x		0.207y	8.817x		0.690y	6.515x	

Means followed by a similar letter within a column (a, b) or row (x, y) are not significantly different at the probability level 0.05 using Duncan's Multiple Range Test.

Figure (1): Distribution of accumulated cadmium percentage in the roots, stem and leaves of both cypress and red gum seedlings after 20 months.

Furthermore, Dixit *et al.*, (2001) on pea plants, noticed increasing in activities of antioxidative enzymes in Cd-treated plants then they suggested that they have some additive function in the mechanism of metal tolerance in the plants. On the other hand, accumulation of cadmium in the leaves of red gum more than roots and stems is agreed with Abouelkhair, (1988) on eucalyptus seedlings and Banko *et al.*, (2002) and Salt *et al.*, (1995) on different perennials and may due to red gum is a high transpired tree. Movement of cadmium from roots to shoots is likely to occur via the xylem and to be driven by transpiration from the leaves. Evidence for this was provided by Salt *et al.* (1995) who suggested that the process of Cd transport from solution through the root and into the xylem is mediated by a saturable transport system(s). However, Cd translocation to the shoot appeared to be driven by transpiration. Within leaves, cadmium is preferentially accumulated in tricomes on the leaf surface, and this may be a possible detoxification mechanism. Moreover, the nitrogen encourage the growth of the seedlings that led to increase of transpiration consequently, the mass flow from roots to shoots (Lorenz *et al.*, 1994). The differentiation of accumulated cadmium among roots and leaves of both species possibly be due to the genotype.

Relationship between cadmium concentration in the soil and cadmium uptake

The non-cadmium treatments (T2, T4 and T6) were eliminated from this analysis to obtain a realistic relationship between the cadmium concentration in soil (X_1) and cadmium levels in both leaves and roots (X_2). Linear correlation between Cd concentrations of leaves and roots from the three cadmium treatments (T1, T3 and T5) indicated that leaves and roots of red gum is highly significant (0.99 and 0.96, respectively). Likewise, the effect of cadmium contamination in the soil was positive on leaves of cypress seedlings with mediated correlation coefficient of 0.85 but the roots of the same species was not significant with the soil cadmium (Table 6).

Table (6): Correlation coefficient between cadmium concentrations in leaves and roots and cadmium concentration in the soil of both cypress and red gum seedlings.

Species	Partitioning	Correlation coefficient
Cypress	Leaves	0.85**
	Roots	0.44 n.s.
Red gum	Leaves	0.99***
	Roots	0.96***

, * = Indicates significance at 0.01 level
n.s. = non significant

The above mentioned results revealed that the leaves and roots of red gum species is strongly capture and accumulate cadmium ion from the contaminated soil with a high efficiency rather than the cypress where its leaves only is capable to accumulate the translocated cadmium but the roots has not the ability to capture a large quantity of this metal. This conclusion confirm the results of Mitchel and Fretz, (1977) and Kubou *et al.*, (1986) that they found a positive correlation between cadmium levels in the growth medium and its concentration in the tissues of white pine, red maple and Norway spruce trees.

Recommendation

The obvious ability of *Eucalyptus camaldulensis* Dehn. (red gum) to accumulate cadmium raises the possibility of using this trees as a phytoextractor around industrial and urban areas where the environment is contaminated by these metal. However, this function will increase by adding nitrogen fertilizer to this tree species.

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قدرة كل من السرو والكافورعلى علاج التربة الملوثة بالكادميوم تحت ظروف التسميد النيتروجينى

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*** مركز البحوث الزراعية- معهد بحوث البساتين- محطة بحوث البساتين بالصبحية - قسم بحوث النبات والأشجار الخشبية**

**** المركز القومى للبحوث- قسم تغذية النبات**

تم إجراء تجربة أصص في صوبة محطةِ بحوثِ البساتين بالصبحية بالاسكندرية للتَحقق من قدرةَ شتلات كلا من السرو والكافور على علاج التربة الملوثة بالكادميوم. تم إضافة ثلاثة مستويات من الكادميوم (صفر، ٣٠،٦٠مجم / كيلوجرام تربة) على صورة كلوريد كادميوم بالإضافة إلى مستويين من النتروجين (صفر، ٣٠٠ مجم/ كيلوجرام تربة) على صورة كبريتات أمونيوم إلى تربة الشتلات المنزرعة. أخذت القياسات التالية لكل من جنسى الأشجار :- الإرتفاع، القطر،عدد الأوراق ، الكتلة الحية، وكمية الكادميوم الممتص في الجذور والساق والأوراق. تم اختبار علاقة الإرتباط ما بين تركيز الكادميوم بالتربة ومحتواه في الأوراق والجذور لكل من السرو والكافور.

أهم النتائج المتحصل عليها كانت كما يلي:-

- محتوى التربة من الكادميوم لم يختلف معنويا بالنسبة لشتلات كل من الكافور والسرو بالرغم من أن تربة شتلات الكافور احتوت على تركيز منخفض من الكادميوم مقارنة بتربة شتلات السرو. وجد أن إضافة جرعة من النيتروجين مع المعدل المنخفض من الكادميوم (٣٠ جزء فى

المليون) قلل تركيز العنصر فى التربة بمقدار ٢٩%، وبالمثل فإن نفس الجرعة من النيتروجين عند إضافتها مع المعدل المرتفع من الكادميوم قللت من تركيز العنصر بالتربة بمقدار ٤٦%.

- وجد أن معاملات الكادميوم المختلفة لم يك لها أى تأثير على عدد الأوراق ، بينما كـان لهـا تأثير معنوى ضعيف على تقليل النمو الطولى لكلا النوعين من الشتلات.
- النمو القطرى زاد نتيجة المعاملة بالتركيز المرتفع (٦٠ جزء فى المليـون) بـدون إضـافة النيتروجين مقارنة بالمعاملات الأخرى، وعند إضافة النيتروجين لنفس التركيز من الكـادميوم فإن النمو القطرى اخفض بشدة.
- وجد أن الكتلة الحية (الوزن الرطب والجاف) لكل من الأوراق والسيقان تزداد بزيادة تركيـز الكادميوم من ٣٠ إلى ٦٠ جزء فى المليون، بينما زادت الكتلة الحية للجذور فى التركيز المرتفع من الكادميوم فقط.
- عند إضافة النيتروجين لمعدلات الكادميوم المستخدمة فإنها زادت من الكتلة الحية لكلا النوعين من الشتلات.
- وجد أن تركيز عنصر الكادميوم فى الجذور والسيقان والأوراق وبالتالى فى النبات ككل يزداد بزيادة المعاملة لكلا النوعين من الشتلات.

أثبتت نتائج هذه الدراسةِ أن الكافور يعتبر ذو كفاءة عالية فى معالجة التربـة الملوثـة بالكادميوم كما أن إضافة السماد النيتروجينى لهذة النوعية من الأرض يحسن من كفاءة امتصاص هذا العنصر الملوث بواسطة الأشجار المنزرعة.