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RECYCLING OF BIOTREATED TANNERY WASTEWATER IN PLANTING OF SOME HYEPERACCUMULATION SHRUBS AND TIMBER TREES SPECIES

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ABSTRACT

This study was carried out in greenhouse at Sinai development project, Ministry of Agriculture, North Sinai, Egypt, for three months to investigate the effect of the irrigation by different treatments (0,25,50,75 and100%) of bio-treated tannery wastewater on growth parameters of three shrubs and seven timber trees seedlings. The results showed that a gradual reduction in growth and biomass production of different seedlings with increasing application of Cr (VI) in irrigation water. Hence, the total dry weight was high significant different between control and different treatment of Cr(VI), but the irrigation by 25% bio-treated tannery wastewater gave the high growth parameter and the total dry weight reached 2.054 gm to followed by the other treatments.

There were a gradual increase in Cr (VI) concentration in shoot, root, total uptake and translocation from root to shoot with increasing application of Cr (VI) in irrigation water. The irrigation with 100 % bio-treated tannery wastewater gave the high chromium concentration in shoot, root, total and total uptake (14.82, 37.21, 52.01 and 71.16 µg g^{-1}, respectively) followed by other treatments. However, there was no significance difference between translocation from root to shoot of chromium with different treatments, and there is no effect on the percentage of infection by VAM under high concentration of Cr (VI). Different seedling show different tolerance levels of Cr (VI) pollution. *Pinus halepensis* is the most sensitive species to Cr (VI). In contrast *Jatropha curcas, Pongamia pinnata* and *Albizzia lebbek* are the most resist and hyperaccumulation species, and chromium accumulation in seedlings tissues was in order of roots › shoots. So, it was suggesting that these species could be employed in phytoremedion of soils contaminated with Cr (VI), and recycling of bio-treated tannery wastewater in shrubs and timber trees nursery.

Keywords: Bio-treated tannery wastewater, biomass, hyperaccumulation species

INTRODUCTION

With increasing urbanization, industrialization and human population, the world must dispose off an ever increasing amount of wastewater both from homes and industries (Solaimalaia *et al*., 2003). Therefore, in the developing countries heavy metals pollution becomes serious due to mining , mineral smelting and tannery industry (Wang *et al* ., 2001) .

This wastewater especially tannery wastewater often pose problems of environment friendly disposal in one side and the mounting stress for irrigation purposes. Alternative methods of bio-treated tannery wastewater irrigation in agriculture are assuming paramount importance to solve the problem of disposal and thus avoid environmental pollution.

Phytoextraction, a plant based technology for the removal of contaminants and heavy metals from polluted waters and soils, is evolving rapidly (Shah *et al*., 2008). Plants are reported to be used to clean wastewater for decodes because they serve as effective biological sieves and inhibits contamination of ground water sources through extensive root system (Karpiscak *et al* ., 1996) . Many researchers have investigated plant species capable of accumulating unwanted metal elements (Sanità di toppi and Gabbrielli, 1999 and Rout *et al*., 2000). Reeves and Baker (2000) compiled a list of plant species that hyper-accumulate Cd, Cr, Ni, Pb, Se, and Zn.

An ideal plant for environment clean up and metal phytoremediation can be envisaged as one with biomass production, combined with superior capacity for pollutant tolerance, degradation and accumulation which are determined by metal uptake, root-shoot translocation, intercellular sequestration, chemical modification and general stress resistances depending on the type of pollutant and the plant species (Pilon-Smits and Pilon, 2002). Finding the optimum plant species for remediation of a determined soil will be the main point controlling the success of the process, as well as the selection of adequate soil amendments which would improve soil conditions allowing plant survival and growth. The physicochemical properties of heavy metals contaminated soils tend to inhibit plant growth (Sopper, 1993).

Recently, new experimental data for using soil microorganisms in bioremediation are emerging (Barae *et al*., 2003); the arbuscular mychorrizal fungi (AMF) deserve special attention. They can influence plant community development, nutrient uptake water relation and above-ground productivity (Jeffries *et al*., 2003), and they may also influence the uptake of contaminants from the soil by their plant partners (Galli *et al*., 1994 ; Liu *et al*., 2000 and Jurkiewicz *et al*., 2004).

The present study aimed to:

i) Select the management of bio-treated tannery wastewater in irrigating of shrubs and timber trees seedlings and their AMF symbioses.

ii) Evaluate the hyperaccumulators of shrubs and timber trees species, which could be used in phytoremediation.

MATERIALS AND METHODS

The experiment was carried out in the greenhouse at Sinai development project-Ministry of Agriculture, North Sinai, Egypt during, the period from 1st April to 30th June 2009.

The experimental design

The split plot design in randomized complete block design (RCBD) was used in analyzing the experimental data as described by Snedecor (1956). The experiment consisted of three replicates. Each replicate contained four treatments: 25%, 50%, 75%, and 100% bioremediation tannery wastewater (diluted with fresh water) in addition to the control. A control set received freshwater irrigation. Each sub plot consisted of 21 seed for each species or 1 gram seeds (about 100 seed) for uncounted species and thinning to 21 seedlings after seed germination.

Investigated plants:

Seven timber tree species and three shrubs species were used in this study: *Albizzia lebbek, Casuarina glauca, Eucalyptus citriodora, Eucalyptus gomphocephala, Leucaena leucocephala, Melia azedarach, Pongamia pinnata, pinus halepensis Jatropha curcas* and *Simmondsia chinensis.* The timber trees species have been introduced in Egypt more than a hundred years ago. These are a fast growing species, these grow well under different soil types, and these are used as a windbreak. The timber is used for pulp production, plywood manufacture, charcoaling and furniture. The shrubs species are perennial woody shrub and are cultivated to provide a renewable source of unique high-quality oil specially,*Simmondsia chinesis* and *Jatropha curcas*.

Experimental procedure:

Seeds were surface sterilized in 0.5% sodium hypochlorite solution for 20 min and washed thoroughly with distilled water. The seeds were grown by direct seeding in plastic boxes (12cm h. x 33cm d. x 38cm l.), about 2.5 cm from the rim. Each box contained 12 Kg sandy soil, mixed with peat moss (1 peat moss / 3 sandy soils). Each seedlings box was irrigated three times weekly using 1000 ml of the bio-treated tannery wastewater at above mentioned dilutions, in parallel with controls. Height and diameter was recorded at the end of the experiment. Then, the seedlings were lifted carefully from the plastic box. The soil particles were then removed from root by washing with tap water. About 1 gm fresh hair root samples clearing and staining to measurement of infection roots percent by the methods of Giovannetti and Mosse(1980). Each seedling was divided into root and shoots and dried at 70^{o}c for 48 hours to constant weight, prior to chromate analysis (Chapman and Patt, 1961).

Soil analysis:

Soil analysis was determined according to Page *et al.* (1982). The amount of available chromium Cr(VI) was extracted by DTPA-reagent and the concentration of metal was measured by atomic absorption spectrophotometer.

Wastewater source:

Composite wastewater samples were collected from selected tanneries in old Cairo after the chromium tanning stage.

Bio-treatment of tannery wastewater:

Table (2) illustrates the wastewater quality before and after the combined treatment (lime precipitation followed by bio-treatment process in sand columns), where 98.4% of Cr(VI) could be removed and COD of the effluent was reduced by 77% (Abdulla *et al.* 2008).

Water analysis:

Tanning wastewater analysis was determined according to APHA (2000). pH was measured using a digital electrode pH meter (Testo® 240). Turbidity was measured using Digital Nephlo meter (Monitok Model 21) after calibration with readymade standards. Chemical Oxygen Demand (COD) was determined according to the calorimetric method. Atomic absorption measurement of total chromium (Cr) was performed after acidifying with nitric acid.

Soil characters

The physical and chemical properties are shown in table (1).

Table (1): the main chemical and physical properties of the used soil

parameter	Value
pH*	8.1
E.C (ds m^{-1})**	0.104
Water soluble cations (meq L^{-1})	
Ca^{++}	0.4
Mg^{++}	0.5
Na^{+}	0.1
K^{+}	0.15
Water soluble anions (meq –L^{-1})	
Co_3^{--}	0.0
HCO_3^{-}	0.5
Cl^{-}	0.5
SO_4^{--}	0.15
Available chromium Cr (VI) (mg kg^{-1})	0.0
Texture	Sandy soil

***Measured in 1:2:5 soil water suspension **Measured in the saturated soil paste water extract**

Table (2): Efficiency of combined chemical/biological technique in tannery wastewater treatment

Parameter	Raw tannery wastewater	After the combined treatment	Treatment efficiency (%)	Max. limit of criteria & specifications
pH	3.1 ± 0.03	6.8 – 7 ± 0.1	-	6 - 9
Color	Dark green	Free of colouring materials	-	Free of colouring materials
COD mg/l	3538 ± 13.4	813 ± 6.9	77%	100
Turbidity NTU	83.5 ± 4.5	16 ± 1.5	81%	50
Cr (VI) mg/l	625 ± 7.8	10 ± 0.5	98.4%	0.5
Cr (Total) mg/l	2250 ± 9.2	15 ± 1.2	99.3%	1

RESULTS AND DISCUSSION

Growth parameter under chromium stress

Data of plant growth is measured at the end of exposure, therefore the response of shrubs and timber trees seedlings due to pollutant exposure were assessed by the shoots height, stem diameter, fresh and dry weights.

Shoot height

The seedlings height was measured at the end of the experiment. The data in table (3,4) showed that shoot height was significantly affected by different species, different chromium treatments and the interaction between species and chromium treatment.

Jatropha curcas had the highest average height (26.26 cm), followed by *C*. *glauca*, *P*. *pinnata* and *S*. *chinensis* (16.54, 15.27 and 14.4 cm, respectively) compared with the control. The average height of control was (15.78 cm), followed by 25 % in the chromium treatment (13.83 cm). The lowest average height was (11.54 cm) which recorded under irrigation by 100% Cr (VI) treatment and there was no significant different between this treatment and 50 and 75% chromium treatments (Table 3).

Stem diameter

The stem diameter was significantly different among chromium treatments in the ten species, and *J. curcas* gives the highest stem diameter (0.99 cm) in the opposite *E. gomphocephala* and *C. glauca* which gave lowest stem diameter (0.114 and 0.116 cm, respectively). On the other hand, the irrigation with 100% Cr (VI) bio-treated wastewater gave the lowest stem diameter (0.235 cm) as compared with the other treatments. However, the control treatment gives the highest stem diameter (0.305 cm) followed by the other treatments, (Table 3).

Total fresh weight

Table (3) shows the total fresh weight production of shrubs and timber trees seedlings as affected by application of various treatments of chromium. *Jatropha curcas* seedlings gives the highest total fresh weight (8.67 gm) followed by *P. pinnata* (6.56 gm). In case of Cr (VI) treatments, the total fresh weight showed no significant difference among treatments but it showed significant different between control (4.064 gm) and other chromium treatments.

Total dry weight

It is clear that species–chromium treatments interaction effects were significantly different for total dry weight. Data presented in Table (3) indicated that *J. curcas* seedlings gave the highest total dry weight (5.005 gm) as compared with the other species, followed by *P. pinnata* (3.079 gm). On the opposite, *P. halepensis* seedlings gave the lowest total dry weight (0.506 gm), followed by *E. gomphocephala* and *M._azedarach* seedlings and they are the same (1.065 gm). On the other hand, the total dry weight was not significantly different between chromium treatment as compared with control and the lowest total dry weight were with irrigation by 100% chromium treatment (1.65 gm).

The species–chromium treatments interaction effect was generally evident throughout the experiment, especially with high treatments of Cr (VI) over than 50%. While, in some species, the most of growth parameters were not significant with irrigation by different Cr (VI) treatments, especially with irrigating by high Cr(VI) treatments (75 and 100%). In addition, the data showed a significant response between different species.

3

4

Different species seedlings response was influenced by high concentration of chromium (Tables 3 and 4). These results are approved with the results of Vajpayee *et al.*, (1999), Iqbal and Shazia (2004). Beyond that a significant reduction in growth parameters was recorded as the concentration of Cr(VI) applied was increased. Tripathi *et al*., (1999) reported similar results in an experiment where 200 ppm of Cr (VI) affected the leaf area and biomass of *Albizzia lebbek*.

Reduction in shoot growth could be attributed to the reduction in chlorophyll contents and activity of photo system induced by heavy metal stresses. Similarly, metal elements transported to above ground plant part reduced height by disturbing the cellular metabolism of the shoot(Shanker *et al*., 2005).The results of Shah *et al*., (2011) showed that a gradual reduction in growth and biomass production of *Eucalyptus* seedlings under the influence of external application of Cd and Cr in the growth medium. Similarly, chromium disturbed the nutritional balance of the seedlings through competitive uptake at the binding sites resulting in the reduction of plant growth. Also, the suppression on dry biomass of *leucaena leucocephala* was reported with sufficient concentration of chromium(Iqbal and Shafiq, 1999 b).

Chromium concentration in shoots and roots

Data in table (3) investigated that chromium concentration in shoots and roots were reduced with decreasing Cr(VI) dose in irrigation water and 25% chromium treatment gives the lowest Cr concentration in shoots and roots (4.66 and 11.19 µg g^{-1}, respectively) as compared with the other treatments. In general, chromium accumulation was increased in roots than shoots for all species under all Cr(VI) treatments , (Table 3) .

On the other hand, *Eucalyptus gomphocephala* and *Eucalyptus citriodora* seedlings gave the highest Cr(VI) concentration in shoots (13.24 and 11.95 µg g^{-1}, respectively). So, *A. lebbek* , *E. citriodora* and *E. gomphocephala* seedlings gave the highest Cr concentration in roots (30.66, 30.13 and 27.46 µg g^{-1} , respectively). While, *S. chinensis* seedlings gave the lowest Cr concentration in shoots and roots (3.47 and 8.41 µg g^{-1}, respectively).

Total chromium concentration

Data presented in Table (3) indicated that total Cr concentration was significantly different between species and Cr (VI) treatments, *Eucalyptus citriodora*, *Eucalyptus gomphocephala* and *Albizzia labbek* seedlings gave the highest total Cr concentration (42.08, 40.69 and 37.19 µg g^{-1}, respectively) as compared with the other species. However, *S. chinensis* and *P. pinnata* seedlings gave the lowest total Cr concentration (11.87 and 14.63 µg g^{-1}, respectively). in general , the seedlings irrigated by 100% bio-treated tannery wastewater gave the highest total Cr concentration (52.01 µg g^{-1}) followed by the other Cr(VI) treatments, (Table 3).

Chromium total uptake

Chromium total uptake differed significantly between the species, treatments and species x treatments interaction. In general, a significant uptake of chromium was detected in all species by different treatments as compared with the control (Tables 3 and 4).

Jatropha curcas seedlings gave the highest Cr total uptake (100.82 µg g^{-1}) followed by the other species. Otherwise, *P. halepensis* seedlings gave the lowest Cr total uptake(8.57 µg g^{-1}) as compared with the other species. So, chromium total uptake was affected by the treatments, the seedlings irrigation by 100% bio-treated tannery wastewater gave the highest Cr total uptake (71.16 µg g^{-1}) followed by 75, 50 and 25% treatments (56.52, 41.77 and 28.63 µg g^{-1}, respectively), as shown in Table (3).

Chromium translocation (shoot / root ratio)

The results in Tables (3 and 4) revealed that the highly significant differences between species and interaction. However, chromium translocation form root to shoot (shoot / root ratio) did not differ significantly between the different treatments.

Translocation of chromium from root to shoot was reduced with low Cr (VI) treatment (25 and 50%) for most species as compared with high Cr(VI) treatments(75 and 100%), as shown in Table (3). *Jatropha curcas* seedlings gave the lowest Cr translocation from root to shoot (0.155). Otherwise, *Leucaena leucocephala* seedlings gave the highest Cr translocation as shoot / root ratio (0.682) followed by the other species.

Chromium is non essential and toxic for plant growth hence plants have no specific mechanism for uptake and translocation in plant system. Heavy metal elements (Cr and Cd) effectively compete with the essential nutrients (P, Fe, K, Mg) for rapid entry into the plant system resulting in the reduction in uptake and translocation of essential nutrients in plant parts (Shanker *et al*., 2005). They added that, roots usually accumulate significantly more metal than above ground plant parts might be due to the sequestration in the vacuoles of the root cells, which has been identified as a detoxification mechanism .

In the present study chromium accumulation in seedlings tissues was in order of roots > shoots and increase was proportional to the external application of Cr (VI). Similar results were reported with Nyquist *et al*., 2007 and Shah *et al*., 2011).

Chromium content of the soil

The analysis of rhizosphere soil revealed that irrigation by 100% bio-treated tannery wastewater gave high Cr(VI) content of the soil for *J. curcas* , *A. lebbek* and *P. pinnata* (0.612, 0.002 and 0.504 mg kg^{-1}, respectively)(as shown in fig. 1) as compared with other treatments. It is also noticeable that chromium content of the soil reduced with low Cr (VI) treatments (25%) followed by other treatments. The foregoing results showed, however, the low mean of Cr(VI) content in rhizosphere soil with *P. pinnata* seedlings(0.504 mg kg^{-1}) with 100% Cr(VI) treatments but, *A. lebbek s*eedlings gave the lowest Cr(VI) content in the rhizosphere soil with 25, 50 and 75% (0.06, 0.09 and 0.22 mg kg^{-1}, respectively).

On the other hand, it was considered that, chromium is a strongly toxic because chromium compound in soil are more or less insoluble as the metal ions are tightly bound to humus and clay particles(Jun *et al.*, 2009).

In general, different interactions may be related with the amount of metal added to soil, soil properties, plant species and plant factors (Nogales *et al.*, 1997). With respect to potentially toxic chromium, their concentration did not case phytotoxic effect to the shrubs and tree seedlings species. This may be due to the low concentrations of Cr (IV) in irrigated water and also to the metal concentrations are remained within the permissible level. In addition of the shrubs and tree species were superior capacity for pollutant tolerance, degradation and accumulation.

The root infection percent by VAM fungi

Figure(1) showed that irrigation by different concentration of Cr(VI) did not effect on the mean root infection percent during the three months.

Pongania pinnata and *Jatropha curcas* seedlings gave the high mean root infection percent under irrigation by 100 % Cr(VI) treatment (40 and 40 % , respectively), followed by *Albizzia lebbek* seedlings (30%), as shown in fig. (1).One the other hand, the total uptake of chromium was high in this species especially in the roots as compared with the shoots. This may be due to VAM fungi. And, this fungi plays an important role in metal tolerance and accumulation.

This results obtained are in harmony with the results of Gaur and Adholeya (2004) and Ghorab, 2005. So, Sharma (2007 b) found that inoculation of *J. Curcas* with mycorrhizae significantly increased the uptake of phosphorus and micro–elements(Aluminum, zinc, chromium, copper, iron and lead).

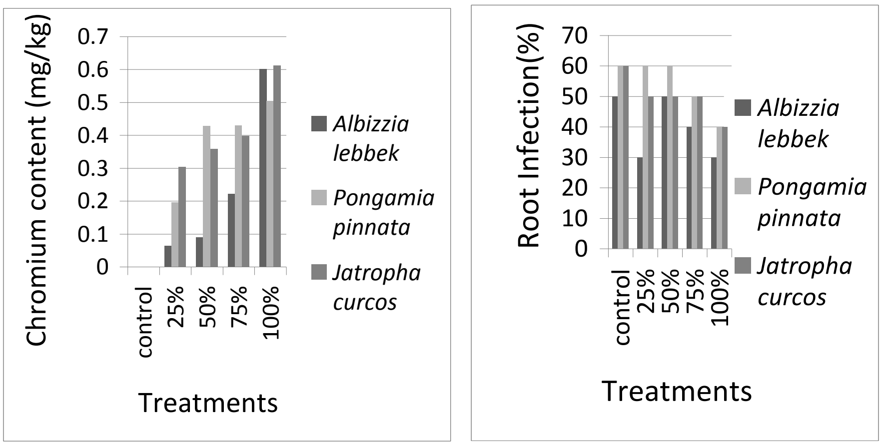

Fig.(1): Effect of irrigation with different treatments of bio-treated tannery wastewater on chromium content (mg kg^{-1})in soil and root infection (%) at the end of the experiment

Conclusion

The results demonstrate a gradual reduction in growth and biomass production of different species seedlings with increasing application of Cr(VI) in irrigation water. Otherwise, there were a gradual increase in chromium concentration in shoot, root, total, total uptake and translocation with increasing application of Cr(VI) in irrigation water. So, chromium accumulation in seedlings tissues was in order of roots>shoots.

This study concluded that *Pinuse halepensis* is the most sensitive species to Cr(VI).By contrast, *Jatropha curcas, Pongamia pinnate* and *Albizzia lebbek* are the most resist and hyperaccumulation species. So, the importance of selecting species and their VAM symbioses on the basis of not only growth but also nutrient accumulation to optimize renovation of bio-treated tannery wastewater and phytoremediation by tree plantations.

It is also clear that Cr (VI) concentration in irrigation water were lower than the excessive or toxic levels, Specially with high treatments. Hence, we can reuse bio-treated tannery wastewater to cultivate hyperaccumulation shrubs and timber trees species in a simple nursery for phytoremediation or green technology.

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أعادة تدوير ماء الصرف الناتج من مصانع دباغة الجلود المعالج بطرق حيوية في زراعة بعض أنواع الشجيرات والأشجار الخشبية العالية التراكم

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أجريت هذه التجربة بالصوبة التابعة لمشروع تطوير النظم الزراعية بشمال سيناء والتابع لوزارة الزراعة ؛مصر ؛لمدة ثلاثة أشهر وذلك لدراسة تأثير تركيزات مختلفة(صفر؛٢٥؛٥٠ ؛٧٥؛١٠٠ %) من ماء الصرف الناتج من مصانع دباغة الجلود والمعالج بطرق حيوية على نمو شتلات ثلاثة أنواع من الشجيرات وسبعة أنواع من الأشجار الخشبية.وقد أوضحت النتائج الأتي:-

لوحظ انخفاض تدريجي في النمو ومحصول الكتلة الحيوية لشتلات الأنواع المختلفة مع زيادة تركيزات الكروم السداسي في ماء الرى.كما كان هناك زيادة معنوية للكتلة الحيوية الكلية للكنترول مقارنة مع تركيزات الكروم السداسي المختلفة. وقد أعطى التركيز ٢٥% من الماء المعالج في ماء الري أعلي مقاييس للنمو .وقد كان الوزن الجاف الكلي ٢.٧٤ جرام تلاه التركيزات الأخرى.

وبالعكس فأن هناك زيادة متدرجة في تركيزات الكروم السداسي في المجموع الخضري والجذري والكلى والامتصاص الكلى للعنصر وانتقال العنصر من المجموع الجذري إلي المجموع الخضري مع زيادة تركيز الكروم السداسي في ماء الري.وقد أعطى الري بتركيز ١٠٠% من الماء المعالج حيويا أعلى تركيزات للكروم في المجموع الخضري والجذري والكلي والامتصاص الكلي للعنصر(١٤.٨٢و٣٧.٢١ و ٥٢.٠ و٧١.١٦ ميكروجرام /جرام؛ على التوالي) مقارنة بالمعاملات الأخرى. بينما لم تظهر النتائج فروق معنوية لانتقال العنصر من المجموع الجذري إلي المجموع الخضري تحت مختلف التركيزات. وأيضا لم يكن هناك تأثير للتركيزات العالية من الكروم علي نسبة الإصابة بفطر الميكوريزا الداخلية التغذية.

ومن ناحية أخرى أظهرت الأنواع المختلفة تحت الدراسة مستويات مختلفة من تحمل الكروم السداسي في ماء الري .فقد كان الصنوبر الحلبي أقل الأنواع تحملا للكروم مقارنة بمختلف الأنواع الأخرى. وعلي العكس فقد كانت الجتروفا والبونجاميا واللبخ أكثر الأنواع تحملا للتركيزات العالية من الكروم السداسي وأيضا أكثرها تراكم لهذا العنصر في الأجزاء النباتية. وقد كان تركيز العنصر بصفة عامة لكل الأنواع في المجموع الجذري أعلي من المجموع الخضري.لذا يقترح استخدام مثل هذه الأنواع الأكثر تحملا والأكثر تراكما للكروم السداسي في داخل أنسجتها في أعادة تدوير مياه دباغة الجلود المعالجة حيويا في مشاتل الأشجار الخشبية.

قام بتحكيم البحث

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Table (3): Mean values of seedlings height(cm), stem diameter(cm), total fresh weight(gm/ plant), total dry weight(gm/ plant), chromium content in shoot(µgg-1) , chromium content in root(µgg-1) ,total chromium uptake(µgg-1) and translocation of chromium from root to shoot (shoot/root) affected by different chromium treatments during three months.

Species	Treatments	Height (cm)	Diameter (cm)	Total fresh w.(gm)	Total dry w.(gm)	shoot conc. μgg^{-1}	Root conc. μgg^{-1}	Total conc µgg-1	Total uptake μgg^{-1}	shoot/root conc.
A. lebbek		12.32 d	0143 de	2.056 de	1.556 d	6.53 cd	30.664 a	37.195 a	54.528 b	0.165 c
C. glauce		16.54 b	0.116 e	2.579 de	1.986 c	8.97 b	12.886 c	21.86 c	41.554 c	0.544 ab
E. citriodora		7.78 e	0174 d	1.821 e	1.228de	11.95 a	30.138ab	42.081 a	47.887bc	0.334 bc
E.gomphocephala		9.34 e	0.114	1.911 e	1.065 e	13.24 a	27.464ab	40.699 a	41.296 c	0.426 abc
L. leucocephala		12.14 d	0.17 d	2.926 d	2.116 c	7.70 bc	13.849 c	21.558 c	44.928bc	0.682 a
M. azedarach		13.36cd	0.146 de	1.888 e	1.065 e	5.89cde	16.972 c	22.871 c	24.246 d	0.272 bc
P. pinnata		15.27bc	0.319 b	6.561 b	3.079	5.91cde	8.728 d	14.638de	52.84 b	0.489 abc
P. halepensis		4.0 f	0.184 d	0.865 f	0.506 f	4.89cde	14.127 c	19.019cd	8.573 e	0.192 c
J. curcas		26.26 a	0.99 a	8.676 a	5.005 a	3.69 e	26.063 b	29.753 b	100.827a	0.155 c
S. chinensis		14.4bcb	0.238 c	4.139 c	2.212 c	3.47 e	8.409 d	11.879 e	25.525 d	0.379 abc
L.S.D 0.05		2.175	0.036	0.927	0.396	2.24	3.965	4.772	10.474	0.303
	cont.	15.78 a	0.305 a	4.064 a	2.55 a	0	0	0	0	0
	25%	13.83 b	0.264 b	3.134 b	2.054 b	4.66 d	11.195 d	15.855 d	28.635 d	0.367 a
	50%	12.38 c	0.246 bc	3.318 b	1.852 b	6.92 c	20.32 c	27.226 c	41.772 c	0.398 a
	75%	12.16 c	0.245 bc	3.272 b	1.805 b	9.75 b	25.94 b	35.684 b	56.521 b	0.583 a
	100%	11.54 c	0.235 c	3.149	1.65 b	14.82 a	37.21 a	52.012 a	71.16 a	0.471 a
L.S.D 0.05		1.147	0.021	0.612	0.461	1.478	1.739	2.265	8.495	0.219

Mean values sharing the same letters are not significantly different at 5% level

Table (4): Mean values of seedlings height(cm), stem diameter(cm), total fresh weight(gm/ plant), total dry weight(gm/ plant), chromium content in shoot(µgg-1) , chromium content in root(µgg-1) ,total chromium uptake(µgg-1) and translocation of chromium from root to shoot (shoot/root) affected by different chromium treatments during three months.

Species	Treatments	Height (cm)	Diameter (cm)	Total fresh w.(gm)	Total dry w.(gm)	Shoot conc. μgg^{-1}	Root conc. μgg^{-1}	Total conc. µgg-1	Total uptake μgg^{-1}	shoot/root conc.
A. lebbeck	cont.	12.90a	0.184a	2.773a	1.83a	0	0	0	0	0
	25%	10.66 a	0.116a	2.446a	1.52a	2.48b	13.24d	15.72c	24.17bc	0.174a
	50%	13.34 a	0.184a	2.696a	1.73a	8.55a	36.62c	45.16b	80.86ab	0.226a
	75%	10.34 a	0.10a	2.326a	1.39a	10.05a	43.14b	53.18b	71.73ab	0.236a
	100%	14.34 a	0.13a	2.290a	1.33a	11.57a	60.33a	71.91a	95.88a	0.190a
L.S.D 0.05		9.68	0.083	1.24	1.22	4.41	6.23	8.76	63.88	0.144
C. glauca	cont.	17.16 a	0.16 a	2.696 a	2.17 a	0	0	0	0	0
	25%	16.34a	0.10 b	2.526 a	2.00 a	5.22 d	11.77 b	16.99 c	33.25 c	0.75 b
	50%	16.84 a	0.10 b	2.37 a	1.87 a	9.25 c	13.41b	22.65 bc	40.82 c	0.72 a
	75%	16.16 a	0.10 b	2.743a	1.95 a	13.62 b	16.54 ab	30.15 b	57.78 b	0.83 a
	100%	16.16 a	0.12 ab	2.56 a	1.94 a	16.79 a	22.72 a	39.51 a	75.86 a	0.75 a
L.S.D 0.05		1.33	0.053	0.948	0.71	3.14	5.69	8.54	16.49	0.16
E. citriodora	cont.	10.24 a	0.1 b	1.943 a	1.35 a	0	0	0	0	0
	25%	9.84 a	0.08 b	1.996 a	1.42 a	10.66 b	21.49 c	32.15 c	45.28 b	0.49 a
	50%	6.0 b	0.08 b	1.833 a	1.25 a	10.48 b	27.25 bc	37.74 bc	46.92 b	042 a
	75%	8.5 a	0.1 b	1.73 a	1.12 a	13.33 b	36.36 b	49.69 b	54.86 b	0.37 a
	100%	4.34 b	0.5 a	1.603 a	1.01 a	25.25 a	65.58 a	90.83 a	92.37 a	0.38 a
L.S.D 0.05		2.06	0.034	0.474	0.462	6.35	9.32	12.25	11.98	0.241
E.gomphocephala	cont.	14.34 a	0.16 a	2.053 a	1.18 a	0	0	0	0	0
	25%	12.5 a	0.12 b	1.923 ab	1.09 ab	9.07 bc	13.23 c	22.31 c	24.14 c	0.65 a
	50%	6.16 b	0.12 b	1.92 ab	1.05 ab	10.15 b	41.75 ab	51.91 b	54.88 b	0.25 ab
	75%	7.66 b	0.1 b	1.876 ab	1.05 ab	14.75 b	34.79 b	49.55 b	51.99 b	0.53 a
	100%	6.0 b	0.06 b	1.783 b	0.95 b	32.2 a	47.54 a	79.74 a	75.46a	0.69 a
L.S.D 0.05		2.04	0.046	0.259	0.213	9.86	12.66	12.01	15.34	0.461
L. leucocephala	cont.	14.34 ab	0.24 a	3.016a	2.21 a	0	0	0	0	0
	25%	15.0 a	0.18 ab	2.936 a	2.14 a	7.52 b	16.99 a	24.51 a	52.11 a	0.45 a
	50%	10.66 bc	0.14 b	2.703 a	1.88 a	7.96 b	18.68 a	26.65 a	49.85 a	0.43 a
	75%	11.5 abc	0.16 ab	3.096 a	2.29 a	9.57 ab	13.8 a	23.37 a	53.9 a	0.45 a
	100%	9.16 c	0.14 b	2.88 a	2.06 a	13.49 a	19.77 a	33.26 a	68.78 a	0.67 a
L.S.D 0.05		3.85	0.087	0.619	0.63	4.79	9.29	11.09	29.51	1.94
M. azedarach	cont.	17.34 a	0.16 a	2.12 a	1.1 a	0	0	0	0	0
	25%	12.16 b	0.15 a	1.74 a	1.05 a	3.48 d	15.46 c	18.95 d	20.41 c	0.25 b
	50%	12.0 b	0.15 a	1.746 a	1.06 a	5.57 c	18.66 bc	24.25 c	25.55 bc	0.3 ab
	75%	12.34 b	0.14 a	2.04 a	1.04 a	9.26 b	22.94 b	32.2 b	33.22 ab	0.41 a
	100%	13.0 b	0.14 a	1.796 a	1.07 a	11.17 a	27.78 a	38.96 a	42.06 a	0.41 a
L.S.D 0.05		1.86	0.041	0.696	0.25	1.91	4.83	5.18	9.83	0.14
P. pinnata	cont.	17.9 a	0.38 a	6.843 a	3.25 a	0	0	0	0	0
	25%	17.3 ab	0.35 ab	6.71 a	3.30 a	2.56 cd	4.94 d	7.51 cd	24.78 c	0.45 b
	50%	13.66 ab	0.32 ab	6.35 a	2.94 a	5.27 bc	9.57 b	14.84 bc	43.63 bc	0.54 ab
	75%	13.16 b	0.3 bc	6.29 a	2.88 a	8.22 b	12.6 ab	20.81 b	59.94 b	0.64 ab
	100%	14.34 ab	0.25 c	6.613 a	3.03 a	13.5 a	16.53 a	30.03 a	90.99 a	0.82 a
L.S.D 0.05		4.02	0.06	1.003	0.95	4.04	4.35	8.35	32.12	0.27
P. halepensis	cont.	4.16 a	0.18 a	0.953 a	0.58 a	0	0	0	0	0
	25%	4.66 a	0.20a	0.923 a	0.58 a	0	0	0	0	0
	50%	3.70 a	0.16 a	0.936 a	0.56 a	3.62 b	15.64 c	19.26 c	11.07 a	0.22
	75%	3.76 a	0.18 a	0.743 a	0.40 a	8.29 a	24.37 b	32.66 b	13.88 a	0.33 ab
	100%	3.7 a	0.16 a	0.770 a	0.40 a	12.55 a	30.63 a	43.17 a	17.91a	0.41 a
L.S.D 0.05		0.91	0.046	0.258	0.23	4.45	4.54	8.99	10.35	0.14
J. curcas	cont.	35.16 a	1.2 a	13.983 a	9.45 a	0	0	0	0	0
	25%	25.84 b	1.1 ab	6.15 b	5.44 b	3.0 ab	9.23 d	12.23 c	67.05 b	0.31 a
	50%	25.16 b	1.0 ab	8.453 b	3.88 b	3.52 ab	13.67 c	17.18 c	70.22 b	0.25 ab
	75%	25.16 b	0.96 b	7.59 b	3.63 b	5.58 a	44.78 b	50.37 b	184.96 a	0.13 abc
	100%	20.0 b	0.68 c	7.206 b	2.64 b	6.35 a	62.64 a	68.98 a	181.91 a	0.1 bc
L.S.D 0.05		6.85	0.21	5.107	2.74	3.76	3.84	6.54	59.76	0.183
S. chinensis	cont.	14.34 ab	0.26 a	4.26 a	2.36 a	0	0	0	0	0
	25%	14.0 ab	0.24 ab	3.986 a	2.02 a	2.6 b	5.6 b	8.2 b	15.76 cd	0.45 ab
	50%	16.34 a	0.24 ab	4.176 a	2.27 a	4.74 a	7.9 b	12.64 b	28.96 bc	0.65 a
	75%	13.0 b	0.2 b	4.283 a	2.32 a	4.77 a	10.05 b	14.83 b	33.92 ab	0.51 ab
	100%	14.34 ab	0.25 ab	3.99 a	2.09 a	5.25 a	18.49 a	23.74 a	48.98 a	0.28 b
L.S.D 0.05		2.69	0.055	1.033	1.03	1.45	5.44	6.42	16.33	0.25

Mean values sharing the same letters are not significantly different at 5% level