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INFLUENCE OF TANNERY EFFLUENT POTENTIALLY ON PHYTOREMEDIATION OF HEAVY METALS AND SALTS BY TWO HALOPHYTIC SPECIES IPOMOEA PES-CAPRAE SWEET AND CLERODENDRON INERME (L.) GAERTN

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ABSTRACT

Tannery effluent is common throughout the world and it pollutes groundwater ecosystem to produce major amount of heavy metals and it causes to reduce the agricultural crop yield. Phytoremediation of some heavy metals (P, Cr, Cd, Cu and Zn) from that application of diluted tannery effluent by two halophytic species *Ipomoea pes-caprae* and *Clerodendron inerme* was observed in this study. Both the halophytic species are accumulating type and the maximum accumulation of heavy metals was found in the leaves of *Ipomoea pes-caprae* when compared to other species of *Clerodendron inerme*. It is estimated from 1 kg dry weight of plant sample *Ipomoea pes-caprae* accumulated 142.10 mg P, 75.86 mg Cr, 53.06 mg Cd, 83.26 mg Cu and 103.75 mg Zn and in *Clerodendron inerme* (127.27 mg P, 64.60 mg Cr, 46.82 mg Cd, 71.65 mg Cu and 91.64 mg Zn) after 120 days treatment. Nearly 15% of heavy metals and salts removed from effluent soil and frequently cultivated both the species of tannery effluent soil to reduce the toxic level and future used in this soil for agricultural purpose crop improvement.

KEY WORDS : Tannery effluent, Heavy metals, Phytoremediation, Halophytes.

INTRODUCTION

Leather tanning industries have cropped up in India over the past three decades. A total number of 2161 tanneries are located in India and spread across the states of Tamil Nadu, West Bengal, Maharashtra, Punjab, Karnataka, Andhra Pradesh, Bihar and Uttar Pradesh. At present more than 568 tanneries are well established in Dindigul, Erode and Vellore districts of Tamil Nadu (Murali and Rajan, 2012). The major metals at these sites are lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd) and chromium (Cr) (Baskar and Abdul Raheem, 2011). To preserve the natural environment, new methods of remediation using physical, chemical and biological principles are being studied. Some plants have a proven potential for removing the heavy metals from contaminated soil. A great deal of recent studies strongly indicate that halophytic plants could be more suitable for heavy metal extraction mainly from saline soil than glycophytes (Manousaki and Kalogerakis, 2011; Miliæ *et al*., 2012). Many halophytes often have high metal tolerance that is strongly linked to traits for salt tolerance (Duarte *et al*., 2013). The aim of this manuscript we have explored the potential for the different concentrations of diluted tannery effluents on *Ipomoea pes-caprae* and *Clerodendron inerme* to characterize the heavy metals of phytoremediation potential of tannery effluent contaminated soil. In recent years, researchers have undertaken numerous studies on phytoremediation of heavy metal-contaminated saline soils using halophytes (Christofilopoulos *et al*., 2016).

MATERIALS AND METHODS

Plant Material

Two fast growing species of salt marsh halophytic

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herbs like *Ipomoea pes-caprae* Sweet and *Clerodendron inerme* (L.) Gaertn were selected for the characterization and screening for phytoremediation of heavy metals from tannery effluents with special reference for biochemical studies. The experimental site was located at Botanical Garden, Annamalai University, Tamil Nadu, India.

Tannery effluents collection

The raw effluent was collected from the tannery industry situated at Vaniyambadi near Vellore District in clean plastic cans and stored at 4 °C for further studies.

Pot culture experiments

The experiment was conducted in an open-air area with natural light, temperature, and humidity. Red soil and sand (3:1 ratio) free from pebbles and stones were filled in polythene bags. The seedlings / cuttings from the selected species of similar size were transplanted from the nursery bed and planted at the polythene bags. The experiment comprised of the following three set of treatments with five replicates and average values are reported. Plants were watered for every 2-3 days, depending on the evaporative demand. Plants were harvested for experimental purpose at intervals of 30, 60, 90, 120 days. During each and every sampling day, samples were randomly collected, washed thoroughly with tap water followed by distilled water.

Estimation of plant chromium, cadmium, copper, zinc and lead

The plant samples were subjected to dry ashing using 0.5 g of each, and with the aid of a muffle furnace heated to 450 °C for 8 hours. The cool ash was transferred to a fume cupboard and 5 mL concentrated HNO_3 and 15 mL concentrated HCl were added. The mixture was heated on a steam bath for 60 minutes. Contents of the beaker were evaporated to dryness followed by the addition of 1 mL concentrated HNO_3 and reevaporated to dryness. One mL concentrated HNO_3 was again added and the solution warmed. Five mL distilled water was added, the resulting solution warmed again and filtered into a 100 mL flask and made up to mark with distilled water. The solution was used for the determination of Cr, Cd, Cu, Pb and Zn using an atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Estimation of soil chromium, cadmium, copper, zinc and lead

Ten gram of air dried soil was taken in a 150 mL conical flask and 20 mL of DTPA extracting (Triethanolamine: 14.92 g, 1.967 g of dimethylene trianine penta acetic acid and 1.47 g of calcium chloride were dissolved in 500 mL distilled water. The pH was adjusted to 7.3 using 1:1 N HCl and diluted to 1 litre using distilled water). Each flask was covered with stretchable parafilm and secured upright on a horizontal shaker with a stroke of 8 cm with a speed of 120 cycles/ minute. After 2 hours of shaking, the suspensions were filtered through Whatman No. 42 filter paper. The filtrates were analyzed for available chromium, cadmium, copper, lead and zinc using atomic absorption spectrophotometer with appropriate standards (Lindsay and Norvell, 1978).

Statistical analysis

Each experiment was repeated five times and the mean values and standard deviations were then calculated (Snedecor and Cochran, 1967).

RESULTS

Lead

The level of lead in two halophytes cultivated in tannery effluent treated soil and control are presented in the Fig 1 and 2. Maximum accumulation was observed in *Ipomoea pes-caprae* (Leaf 60.90, stem 49.60 and root 31.60 mg/kg dr. wt) followed by *Clerodendron inerme* (Leaf 54.68, stem 43.88 and root 28.65 mg/kg dr. wt) in tannery effluent treated soil when compared to control after 120 day cultivation period with 90% effluent treatment. The minimum accumulation of lead was shown in *Clerodendron inerme* in after 30 days cultivation of control plants (Leaf 1.45, stem 1.20 and root 0.78 mg/kg dr. wt) than equal value in *Ipomoea pes-caprae* (Leaf 1.45, stem 1.20 and root 0.78 mg/kg dr. wt). The highest percentage increase over control potassium accumulation was observed in the leaf of *Ipomoea pes-caprae* than in the root and stem (Leaf 97.61%, root 97.53% and stem 97.07%) followed by *Clerodendron inerme* (Leaf 97.34%, stem 97.26% and root 97.21%) at 90% of tannery effluent treatment after 120 days of cultivation period. Values shown are mean ± SD for five replicates. In Fig. 2, it is observed that two halophytes cultivated in tannery effluent and control soil, gradually

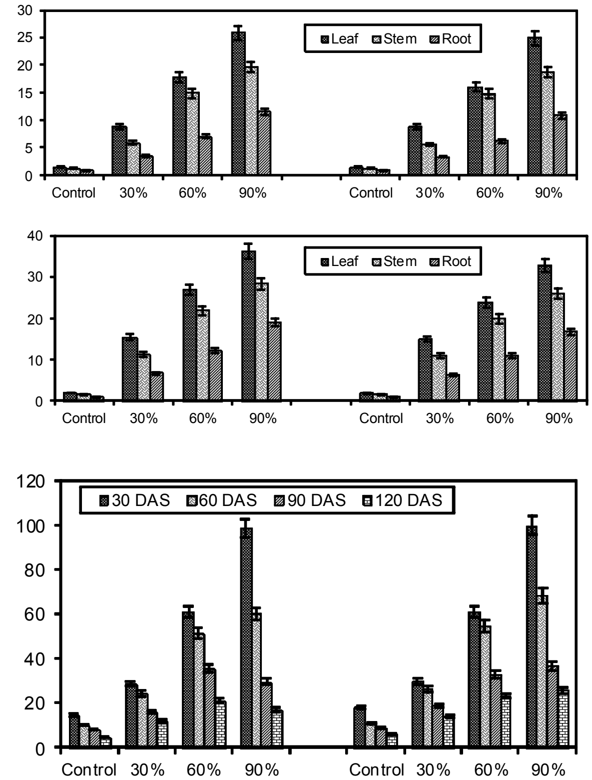

Fig. 1. Effect of different concentrations of tannery effluents on lead content on plant samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

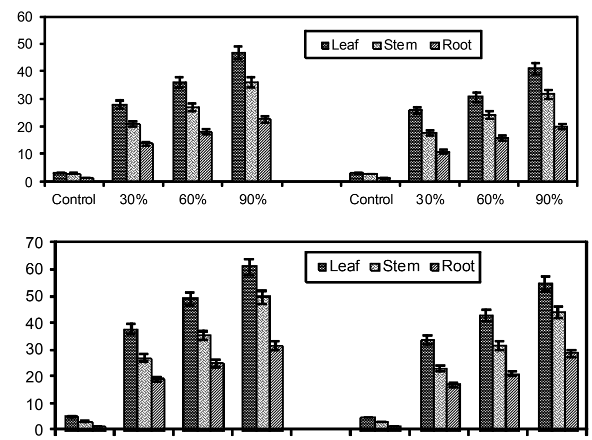

Fig. 2. Effect of different concentrations of tannery effluents on lead content on soil samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

reduced the soil lead when compared to control soil. The maximum reduction was achieved in tannery effluent treated soil, *Ipomoea pes-caprae* (98.85-17.25 mg/kg dr. wt (-473.04% reduction) and *Clerodendron inerme* (100.00-25.85 mg/kg dr. wt (-257.01% reduction) on 120th days after treatment.

Table 1. Effect of different concentrations of tannery effluents on chromium content (mg/kg dr. wt) on plant samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS			60 DAS			90 DAS			120 DAS		
		Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Ipomoea	Control	0.65±0.33	0.40±0.020	0.20±0.010	1.12±0.036	0.72±0.021	0.42±0.043	1.23±0.061	0.98±0.049	0.76±0.038	1.56±0.078	1.10±0.055	0.88±0.044
pes-caprae	30%	3.56±0.178	2.22±0.111	0.90±0.045	10.18±0.509	6.62±0.331	3.00±0.150	1.562±0.781	10.00±0.500	6.22±0.311	19.66±0.983	14.22±0.711	9.18±0.459
	60%	7.85±0.393	4.00±0.200	3.00±0.150	16.22±0.811	9.26±0.463	6.28±0.314	20.52±1.026	12.28±0.614	9.00±0.450	26.88±1.344	18.72±0.936	12.88±0.644
	90%	12.68±0.674	8.66±0.433	5.28±0.264	21.53±1.077	13.30±0.665	8.42±0.421	29.66±1.483	16.29±0.814	11.60±0.580	36.98±1.849	24.20±1.210	14.68±0.734
Clerodendron	Control	0.65±0.033	0.40±0.020	0.20±0.010	1.10±0.055	0.70±0.035	0.40±0.020	1.15±0.057	0.86±0.043	0.72±0.036	1.39±0.070	1.00±0.050	0.80±0.040
inerme	30%	3.50±0.113	2.20±0.110	0.82±0.041	10.22±0.511	5.88±0.294	2.88±0.144	14.26±0.713	8.00±0.400	6.00±0.300	17.65±0.882	12.22±0.611	8.40±0.420
	60%	7.00±0.350	3.90±0.195	3.00±0.150	15.00±0.750	9.00±0.450	6.00±0.300	17.62±0.881	11.44±0.411	8.22±0.411	22.23±1.112	16.19±0.810	11.40±0.570
	90%	12.00±0.600	8.50±0.425	5.20±0.260	20.82±1.026	12.00±0.600	8.00±0.400	27.68±1.384	13.66±0.683	11.00±0.550	30.00±1.500	21.00±1.050	13.60±0.680

Chromium

Accumulation of Chromium in the tissues of *Ipomoea pes-caprae* and *Clerodendron inerme* cultivated in tannery effluent treated soil and control soil are presented in the Table 1 and 2. Higher chromium content was accumulated in after 120 days, halophytes cultivated in 90% of tannery effluent treated soil where, *Ipomoea pes-caprae* accumulated (Leaf 36.98, stem 24.20 and root 14.68 mg/kg dr. wt) followed by *Clerodendron inerme* (Leaf 30.00, stem 21.00 and root 13.60 mg/kg dr. wt). The minimum accumulation of chromium was shown in the two experimental plants after 30 days cultivation of control plants (Leaf 0.65, stem 0.40 and root 0.20 mg/kg dr. wt). The highest percentage increase over control potassium accumulation was observed in the root of *Ipomoea pes-caprae* than in the stem and leaf (Root 98.63%, stem 98.34% and leaf 98.24%) followed by *Clerodendron inerme* (Root 98.52%, stem 98.09% and leaf 97.83%) at 90% of tannery effluent treatment after 120 days of cultivation period. Values shown are mean ±SD for five replicates. From the results (Table 2), it is observed that chromium was considerably decreased in tannery effluent treated soil when compared to control. Highest reduction in chromium was recorded in *Ipomoea pes-caprae* cultivated soil, 84.60-24.50 mg/kg dr. wt (-2435.309% reduction) which was followed by *Clerodendron inerme*, 85.18-29.60 mg/kg dr. wt (-187.77% reduction) after 120 day experimental period at 90% of treatments.

Cadmium

The amount of cadmium accumulated by two halophytes cultivated in tannery effluent treated and control soil were shown in Table 3 and 4. Similar to chromium, the halophytes cultivated in tannery effluent treated soil showed higher accumulation of cadmium, especially in *Ipomoea pes-caprae* leaf followed by stem and root (Leaf 24.98, stem 16.88 and root 11.20 mg/kg dr. wt) than in *Clerodendron inerme* (Leaf 21.60, stem 15.22 and root 10.00 mg/kg dr. wt). The lowest accumulation of lead was shown in both the two experimental plants after 30 days cultivation of control plants (Leaf 0.28, stem 0.20 and root 0.10 mg/kg dr. wt).

The highest percentage increase over control cadmium accumulation was observed in the root of *Ipomoea pes-caprae* than in the stem and leaf (Root 99.10%, leaf 98.87% and stem 98.81%) followed by *Clerodendron inerme* (Root 99.00%, leaf 98.70% and stem 98.66%) at 90% of tannery effluent treatment after 120 days of cultivation period. Values shown are mean ±SD for five replicates. The results shows that halophytes cultivated in tannery effluent soil declined the soil cadmium level (Table 4) and maximum reduction was observed in *Ipomoea pes-caprae* 63.60-16.18 mg/kg dr. wt (-294.93%) followed by *Clerodendron inerme* 64.00-19.18 mg/kg dr. wt (-233.68%) after 120 days of cultivation at 90% effluent level. Values shown are mean ± SD for five replicates.

Copper

The level of copper content in two halophytes cultivated in tannery effluent treated soil and control soil are presented in Table 5 and 6. Maximum accumulation was observed in *Ipomoea pes-caprae* (Leaf 38.756, stem 24.60 and root 19.90 mg/kg dr. wt) followed by *Clerodendron inerme* (Leaf 33.22, stem 20.80 and root 17.63 mg/kg dr. wt) in tannery effluent treated soil after 120 days of experimental period at 90% effluent treatment when compared control. The maximum percentage increase over control was achieved in tannery effluent treated soil (*Ipomoea pes-caprae* 96.80% in leaf, 96.48% in root and 95.93% in stem than in *Clerodendron inerme* (Leaf 96.55%, root 96.14 and

Table 2. Effect of different concentrations of tannery effluents on chromium content (mg/kg dr. wt) on soil samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS	60 DAS	90 DAS	120 DAS
Ipomoea pes-caprae	Control	5.60±0.280	4.00±0.200	3.76±0.188	2.20±0.110
	30%	24.65±1.233	20.18±1.009	16.19±0.810	10.88±0.544
	60%	52.68±2.634	40.66±2.008	30.18±1.509	22.60±1.130
	90%	84.60±4.230	60.05±3.002	42.18±2.109	24.50±1.225
Clerodendron inerme	Control	5.800.290	4.40±0.220	4.00±0.200	2.68±0.134
	30%	25.00±1.250	22.85±1.143	17.66±0.883	13.18±0.654
	60%	55.00±2.750	45.65±2.282	35.17±1.766	28.65±1.433
	90%	85.18±4.259	46.19±2.309	32.85±1.643	29.60±1.480

Table 3. Effect of different concentrations of tannery effluents on cadmium content (mg/kg.dr.wt) on plant samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS			60 DAS			90 DAS			120 DAS		
		Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Ipomoea	Control	0.28±0.014	0.20±0.010	0.10±0.005	0.36±0.018	0.28±0.014	0.18±0.009	0.48±0.024	0.30±0.015	0.24±0.012	0.60±0.030	0.40±0.020	0.30±0.015
pes-caprae	30%	1.88±0.094	1.22±0.061	1.00±0.050	4.68±0.234	2.43±0.122	1.50±0.075	8.62±0.431	4.00±0.200	2.22±0.111	10.65±0.533	7.48±0.374	5.00±0.250
	60%	3.00±0.150	1.90±0.095	1.28±0.064	8.00±0.400	4.22±0.211	2.80±0.140	12.62±0.631	6.90±0.345	4.80±0.240	19.22±0.961	10.40±0.520	6.22±0.311
	90%	7.22±0.361	4.00±0.200	2.20±0.110	14.58±0.729	6.88±0.344	4.42±0.211	20.29±1.015	11.20±0.560	7.00±0.350	24.98±1.249	16.88±0.844	11.20±0.560
Clerodendron	Control	0.28±0.014	0.20±0.010	0.10±0.005	0.340±0.017	0.24±0.012	0.16±0.008	0.042±0.021	0.28±0.014	0.20±0.010	0.54±0.027	0.36±0.018	0.28±0.014
inerme	30%	1.86±0.093	1.20±0.060	1.00±0.050	4.50±0.225	2.30±0.115	1.40±0.070	8.00±0.400	3.80±0.190	2.00±0.100	10.22±0.511	6.90±0.345	4.50±0.225
	60%	2.90±0.145	1.90±0.095	1.20±0.060	7.80±0.390	4.00±0.200	2.60±0.130	11.40±0.570	6.00±0.300	4.40±0.220	16.22±0.811	9.20±0.460	6.00±0.300
	90%	7.00±0.350	4.00±0.200	2.20±0.110	14.00±0.700	6.00±0.300	4.00±0.200	17.28±0.864	9.90±0.495	6.50±0.325	21.60±1.080	15.22±0.761	10.00±0.500

stem 95.67) after 120 days of cultivation. Values shown are mean ± SD for five replicates. From Table 6, it is observed that two halophytes cultivated in tannery effluent and control reduced the soil copper when compared to control soil. The maximum reduction was achieved in tannery effluent treated soil, *Ipomoea pes-caprae,* 96.60-20.58 mg/kg dr. wt (-369.38%) than in *Clerodendron inerme,* 97.00-25.66 mg/kg dr. wt (-278.02%) after 120 days of cultivation. Values shown are mean ± SD for five replicates.

Zinc

Table 7 and 8, revealed that higher accumulation of zinc is found in halophytes cultivated in tannery effluent treated soil when compared to control. Maximum accumulation was observed in *Ipomoea pes-caprae* (Leaf 45.00, stem 34.25 and root 24.50 mg/kg dr. wt) followed by *Clerodendron inerme* (Leaf 39.90, stem 30.19 and root 21.55 mg/kg dr. wt) in tannery effluent treated soil after 120 days of experimental period at 90% effluent treatment when compared control. The highest percentage increase over control was achieved in tannery effluent treated soil (*Ipomoea pes-caprae* 94.71% in leaf, 94.16% in stem and 93.46% in root than in *Clerodendron inerme* (Leaf 94.11%, stem 93.44 and root 92.57) after 120 days of cultivation at 90%. Values shown are mean ± SD for five replicates. The amount of zinc in the soil gradually declined in both the treatments.

Maximum reduction was observed in *Ipomoea pes-caprae*, 126.18-27.56 mg/kg dr. wt (-357.83%) followed by *Clerodendron inerme*, 128.00-34.00 mg/kg dr. wt (-276.47%) after 120 days of cultivation in tannery effluent treated soil when compared to control soil at 90%. Values shown are mean ± SD for five replicates.

DISCUSSION

The present study indicated, after 120 days of cultivation of halophytes at 90% treated with tannery effluent, showed the maximum bioaccumulation of heavy metals. All the heavy

Table 4. Effect of different concentrations of tannery effluents on cadmium content (mg/kg dr. wt) on soil samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS	60 DAS	90 DAS	120 DAS
Ipomoea	Control	2.80±0.140	2.20±0.110	1.50±0.075	1.00±0.050
pes-caprae	30%	14.18±0.709	10.19±0.510	8.00±0.400	7.20±0.360
	60%	38.00±1.900	30.62±1.531	25.88±1.294	16.15±0.808
	90%	63.60±3.180	44.50±2.225	22.18±1.109	16.18±0.809
Clerodendron	Control	3.000.150	2.30±0.115	1.72±0.086	1.32±0.066
inerme	30%	15.00±0.750	12.22±0.611	9.00±0.450	8.10±0.405
	60%	40.02±2.001	33.60±1.680	29.65±1.483	20.18±1.009
	90%	64.00±3.20	46.88±2.3445	25.85±1.293	19.18±0.959

Table 5. E Effect of different concentrations of tannery effluents on copper content (mg/kg dr. wt) on plant samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS			60 DAS			90 DAS			120 DAS		
		Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Ipomoea pes-caprae	Control	1.24±0.012	1.00±0.050	0.70±0.035	2.11±0.105	1.42±0.071	0.90±0.045	2.99±0.149	2.00±0.100	0.98±0.049	4.86±0.243	2.90±0.145	1.22±0.061
	30%	4.00±0.200	2.20±0.110	1.90±0.095	7.98±0.399	3.90±0.195	2.40±0.120	14.88±0.744	8.88±0.444	6.22±0.311	18.66±0.933	11.66±0.583	9.00±0.450
	60%	8.22±0.411	4.42±0.221	2.43±0.122	16.96±0.848	9.00±0.450	6.40±0.320	20.88±1.004	13.22±0.611	10.00±0.500	27.66±1.383	18.90±0.945	13.30±0.665
	90%	14.88±0.744	9.00±0.450	6.28±0.314	21.66±1.083	14.40±0.720	12.40±0.620	28.82±1.441	18.90±0.945	14.88±0.744	1.938±4.42	24.60±1.230	19.90±0.995
Clerodendron inerme	Control	1.24±0.062	0.90±0.045	0.68±0.034	2.00±0.100	1.40±0.070	0.84±0.042	2.50±0.125	1.80±0.090	0.90±0.045	4.42±0.221	2.00±0.100	1.20±0.060
	30%	3.96±0.198	2.20±0.110	1.70±0.085	7.00±0.350	3.70±0.185	2.22±0.111	12.22±0.611	8.00±0.400	6.00±0.300	16.98±0.849	10.90±0.545	7.92±0.396
	60%	8.00±0.400	4.40±0.220	2.20±0.110	14.32±0.716	8.22±0.411	6.00±0.300	17.68±0.884	12.10±0.605	8.22±0.441	26.66±1.333	16.90±0.845	11.65±0.583
	90%	13.22±0.661	9.00±0.450	6.00±0.300	12.82±0.941	14.00±0.700	11.22±0.561	26.00±1.300	16.22±0.811	12.40±0.620	33.2±1.661	20.80±1.040	17.63±0.882

metal amounts are significantly increased with increasing concentrations of tannery effluents up to 90%. For instance, soil heavy metals level was gradually declined with the increasing concentrations of tannery effluents. The lowest values are observed in 30% of control plant in both the experimental plants. Metal deposit in the cell walls as a result of binding to pectic compounds could be also considered as an important mechanism for metal detoxification in halophytic species, as demonstrated in *Halimione portulacoides* (Sousa *et al.*, 2008). Species used for Phytoremediation study, must not only accumulate higher amounts of the larger element but also have a high growth rate, tolerate the toxic effects of the heavy metals, be adapted to local environment and climate, be resistant to pathogen and pests, be easy to cultivate and repulse herbivores to avoid food chain contamination (Ali *et al.*, 2013).

Duarte *et al.* (2013) observed *Halimione portulacoides* is suitable species for Cr(VI) phytoremediation processes through phytoextraction process. Redondo-Gomez (2013) reported that bio-accumulation of metals in roots and tillers of *S. maritima* and *S. densiflora* and described as a feasible method for remediating waters and soils contaminated with heavy metals. Chai *et al.* (2014) have demonstrated that *Suaeda alterniflora* not only endured and sequestrated most heavy metals including Cu, Cd and Pb in belowground parts, but also produced organic acids which chelate with heavy metals to reduce their toxicity. *Suaeda fruticosa* accumulates large amounts of Cd^{2+} and Cu^{2+} in its tissues, especially in roots, suggesting it could be used for decontaminating saline soils polluted by Cd^{2+} and Cu^{2+} (Bankaji *et al.*, 2015).

In the present study, maximum accumulation of Pb, Cr, Cd, Cu and Zn content was observed in

Table 6. Effect of different concentrations of tannery effluents on copper content (mg/kg dr. wt) on soil samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS	60 DAS	90 DAS	120 DAS
Ipomoea pes-caprae	Control	11.90±0.595	9.65±0.483	6.00±0.300	4.65±0.233
	30%	20.00±1.000	18.55±0.927	15.90±0.795	11.00±0.550
	60%	46.80±2.325	40.00±2.000	30.00±1.500	21.65±1.083
	90%	96.60±4.830	62.88±3.100	36.90±1.845	20.58±1.029
Clerodendron inerme	Control	12.000.600	10.00±0.500	6.50±0.325	5.50±0.275
	30%	21.00±1.050	20.00±1.000	16.90±0.845	13.80±0.690
	60%	48.00±2.400	43.44±2.172	35.60±1.780	25.80±1.290
	90%	97.00±4.850	44.85±2.243	38.90±1.945	25.66±1.283

Table 7. Effect of different concentrations of tannery effluents on zinc content (mg/kg dr. wt) on plant samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS			60 DAS			90 DAS			120 DAS		
		Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Ipomoea	Control	2.38±0.119	2.00±0.100	1.60±0.080	4.60±0.230	3.56±0.178	2.22±0.111	6.00±0.300	4.80±0.240	2.98±0.149	8.20±0.410	5.54±0.277	4.00±0.200
pes-caprae	30%	8.86±0.443	5.00±0.250	4.12±0.206	14.90±0.747	9.22±0.461	6.60±0.330	24.30±1.215	16.88±0.844	12.18±0.609	30.55±1.527	21.50±1.075	14.19±0.710
	60%	16.88±0.844	10.44±0.522	6.18±0.309	23.90±1.195	17.92±0.846	11.85±0.592	28.88±1.444	22.68±1.134	16.88±0.844	36.90±1.845	28.22±1.411	18.90±0.945
	90%	22.90±1.145	16.83±0.841	10.00±0.500	26.80±1.340	26.00±1.300	15.26±0.763	35.90±1.795	30.19±1.509	19.22±0.961	45.00±2.250	34.25±0.713	24.50±1.225
Clerodendron	Control	2.35±0.118	1.98±0.099	1.60±0.080	4.20±0.210	3.00±0.150	2.00±0.100	5.18±0.259	4.63±0.232	2.68±0.134	6.58±0.329	5.22±0.261	3.62±0.181
inerme	30%	8.80±0.440	5.00±0.250	4.00±0.200	12.22±0.611	9.00±0.450	6.18±0.309	21.68±1.084	14.25±0.713	10.22±0.511	26.40±1.320	20.10±1.005	12.10±0.605
	60%	16.00±0.800	10.07±0.503	6.12±0.306	21.60±1.080	15.80±0.790	9.90±0.495	25.90±1.295	19.40±0.970	13.27±0.663	32.80±1.640	16.91±0.845	15.00±0.750
	90%	21.60±1.080	16.00±0.800	10.00±0.500	24.10±1.205	22.00±1.100	14.18±0.709	33.28±1.664	29.18±1.459	17.00±0.850	39.90±1.995	30.19±1.509	21.55±1.077

Table 8. Effect of different concentrations of tannery effluents on zinc content (mg/kg dr. wt) on soil samples of *Ipomoea pes-caprae* and *Clerodendron inerme*

Plants	Concentration (%)	30 DAS	60 DAS	90 DAS	120 DAS
Ipomoea	Control	20.00±1.000	33.66±1.683	10.00±0.500	5.18±0.259
pes-caprae	30%	33.66±1.683	26.85±1.343	20.18±1.009	16.18±0.809
	60%	76.80±3.825	60.55±3.027	30.18±1.509	22.28±1.114
	90%	126.18±6.309	96.80±4.84	54.80±2.74	27.56±1.378
Clerodendron	Control	20.001.000	14.18±0.709	12.82±0.641	6.00±0.300
inerme	30%	33.85±1.698	27.19±1.359	23.50±1.125	20.50±1.025
	60%	78.85±3.942	66.90±3.345	33.80±1.690	26.85±1.343
	90%	128.00±6.400	99.25±4.963	58.56±2.928	34.00±1.700

Ipomoea pes-caprae, when compared to control followed by *Clerodendron inerme*. The use of halophytes to extract several toxic metals has received increasing attention since a few years (Ghnaya *et al.*, 2005; Sousa *et al.*, 2008; Ghnaya *et al.*, 2007; Lefevre *et al.*, 2009; Redondo-Gomez *et al.*, 2011; = Milic *et al.*, 2012; Chai *et al.*, 2014; Korzeniowska and Stanislawska-Glubiak, 2015; Christofilopoulos *et al.*, 2016).

CONCLUSION

Based on the results from the present phytoremediation study, it is concluded that salt accumulating halophytes *Ipomoea pes-caprae* and *Clerodendron inerme* are suggested to be better adapted to cope up with heavy metals stress especially *Ipomoea pes-caprae* is highly tolerant to tannery effluents when compared to *Clerodendron inerme*.

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