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Research Article

PHYTOREMEDIATION OF TANNERY EFFLUENT CONTAMINATED SOIL USING *SESUVIUM PORTULACASTRUM*

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ABSTRACT

Tannery is an oldest and fastest growing industry in India. Tannery effluents are ranked as the highest pollutant among all the industrial wastes. The tannery industries are the major disposes of chromium which is harmful to human health and it is toxic, mutagenic, carcinogenic and teratogenic. Phytoremediation is an emerging technology that uses various plants to degrade or immobilize contaminants from soil and water. *Sesuvium portulacastrum* tolerates abiotic constraints such as salinity, drought and toxic metals. Under abiotic stresses (salt, drought and heavy metal), *S. portulacastrum* exhibits various adaptations through morphological, physiological and biochemical changes. The present study investigated the phytoremediation potential of *S. portulacastrum* on removal of salt and heavy metal in tannery effluent contaminated soil. From the results, *S. portulacastrum* accumulated highest Na (62 to 158 mg kg^{-1}) in tap water irrigated with vermicompost applied plants. In effluent irrigated plants highest Na (62 to 136 mg kg^{-1}) was observed in vermicompost applied plants. *S. portulacastrum* accumulated highest chromium (4.01 to 51.25 mg kg^{-1}) was observed in vermicompost applied with tap water irrigated plants. In effluent irrigated plants highest chromium (4.01 to 33.15 mg kg^{-1}) was observed in vermicompost applied plants. *S. portulacastrum* significantly reduced the pH, EC, Na and Cr levels in tannery effluent contaminated soil and correspondingly increased in plant sample. *S. portulacastrum* was an efficient in accumulating salt and heavy metal in their tissue and the phytoremediation studies indicates that *S. portulacastrum* could be used for phytoremediation of tannery effluent contaminated soil.

INTRODUCTION

Worldwide leather industry is one of the most polluting obnoxious and hazardous manufacturing sectors due to generating excessive solid, liquid and gaseous pollutants, which is considered to be a major source of pollution. India alone about 2000-3000 tons of chromium escapes into the environment annually from tannery industries (Altaf *et al.,* 2008). In Tamilnadu, more than 568 tanneries located Erode, Dindigul and Vellore districts (Murali and Rajan 2012). It has been estimated that more than 50,000 ha of productive agricultural lands have been contaminated with Cr alone due to the disposal of tannery wastes in Tamil Nadu, where more than 60 percent of Indian tanneries are located in Vellore district (Sunitha *et al*., 2015). The accumulation of Cr in soil is of major concern because of its possible phytotoxicity or increased movement of metals into the food chain and the potential for surface and groundwater contamination. The chromium contamination in soil has drastically reduced the crop yields (Mahimairaja *et al.,* 2011). The effect of chromium causes a temporary effects such as dizziness, headache, irritation of eyes, skin or lungs, allergic reactions, poisoning of liver, kidney or nervous system or collapse due to lack of oxygen. Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water. This plant-based technique is potentially applicable to a variety of contaminants (Hazrat *et al*., 2013). Use of salt-tolerant plants becomes very attractive for the reclamation of heavy metal polluted sites that were affected by salinity. Since the saline depressions often constitute sites of accumulation of industrial effluents contaminated by heavy metals (Shevyakova *et al*., 2003). Halophytes usually have high tolerance to heavy metals compared with common plants. *Sesuvium portulacastrum* is a common halophyte growing well in adverse surroundings and is exploited mainly for the environmental protection including phytoremediation, desalination and stabilization of contaminated soils. The main objective of the present study

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was to determine the phytoremediation potential of *Sesuvium portulacastrum* on Salt and heavy metal removal in tannery effluent contaminated soil.

Experimental section

Selection of species

Salt marsh halophyte *Sesuvium portulacastrum*. L from Aizoaceae was selected for the analysis of phytoremediation potential of this plant on Salt and heavy metal removal in tannery effluent contaminated soil. The plant tolerates abiotic constraints such as salinity, drought and toxic metals. Under abiotic stresses, *S. portulacastrum* exhibits various adaptations through morphological and anatomical growth, water use efficiency, physiological and biochemical changes. *S. portulacastrum* accumulates high concentrations of salt in their cells and tissues and overcome salt toxicity by developing succulence (Mirza *et al.*, 2014). *S. portulacastrum* is used to decontaminate the soils polluted by heavy metals. *S. Portulacastrum* has the ability to cope with various abiotic stresses, to contribute to success as a pioneer species for environment protection.

Sampling location

The raw effluent was directly collected from the tannery effluent treatment plant in clean plastic cans and tannery effluent contaminated soil was collected near the tannery industry located at Vaniyambadi, Vellore district 12.6950º N latitude and 78.6219ºE longitude. The physical and chemical properties of tannery effluent and tannery effluent contaminated soil were analyzed as per the standard procedure.

Design of the experiment

Tannery effluent contaminated soil free from pebbles and stones were filled in plastic pots. The seedlings with similar size were planted at the plastic pots (Figure 1). The experiments comprised following treatments with 3 replications and average values are reported by adopting Completely Randomized Block Design.

T_1 - Contaminated soil + Tap water irrigation
T_2 - Contaminated soil + Tannery effluent irrigation
T_3 - Contaminated soil + *S. portulacastrum* + Tap water irrigation
T_4 - Contaminated soil + *S. portulacastrum* + Tannery effluent irrigation
T_5 - Contaminated soil + *S. portulacastrum* + Vermicompost + Tap water irrigation
T_6 - Contaminated soil + *S. portulacastrum* + Vermicompost + Tannery effluent irrigation
T_7 - Contaminated soil + *S. portulacastrum* + Farmyard manure + Tap water irrigation
T_8- Contaminated soil + *S. portulacastrum* + Farmyard manure + Tannery effluent irrigation

Figure 1 Overview of pot culture experimental study

Analysis of pH and EC in soil sample

The tannery effluent and soil sample were collected from Vaniyambadi, Vellore district. Soil sample were taken 0, 30, 60 and 90 days after planting. These soil samples were dried, powdered and passed through 2 mm sieve. The sieved soil samples were then taken up for analysis. The pH and EC was estimated by the method of Jackson (1973).

Analysis of pH and EC in plant sample

Five gram of fresh plant sample were ground in mortar and pestle by using water (1:3) and then filtered. This crude extract was used to determine the pH and EC (Ayyapan *et al*. 2016).

Analysis of sodium in soil and plant sample

The mature and fully developed leaves were detached from the twigs and surface dust was washed with distilled water. The leaves are dried. After drying it was used for acid digestion. Soil and plant sodium content was estimated by following the method of (Jackson 1973).

Analysis of Heavy metal (Cr) in soil and plant sample

One gram of the sample was digested with 20 ml of aqua - regia (HCL: HNO_3 at 3:1) (soil sample) / triacid (plant sample) until a clear solution is obtained. The clear digests were allowed to cool and rinsed into 50-mL volumetric flasks and made up to mark with distilled water. Heavy metal content of the digests was determined by Atomic Adsorption Spectrophotometer (APHA 2005).

Statistical analysis

The experimental results were statistically scrutinized as suggested by Panse and Sukhatme (1985) to find out the influence of various treatments on the effluent, soil properties and plants. The critical difference was worked out at ($P \leq 0.05$) probability.

RESULTS AND DISCUSSION

Characterisation of tannery effluent

The important physico-chemical characteristics of tannery effluent samples were analysed. The tannery effluent was blackish in colour with an offensive odour. The pH was 8.32 with an EC of 4.50 dS m^{-1}. It contained large amount of total suspended solids (235 mg L^{-1}) and total dissolved solids (2815 mg L^{-1}). The Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the tannery effluent were (1054 mg L^{-1}) and (2612 mg L^{-1}) respectively.

Characterisation of tannery effluent contaminated soil

The physico-chemical characteristics of tannery effluent contaminated soil samples were analysed. The pH was 8.06 with an EC of 4.01 dS m^{-1}. Large amounts of sodium (652 mg kg^{-1}), chloride (420 mg kg^{-1}), potassium (298 mg kg^{-1})calcium (235 mg kg^{-1}), magnesium (168 mg kg^{-1}), and chromium (482 mg kg^{-1}).

pH and EC of soil sample

Cultivtaion of *Sesuvium portulacastrum* considerably decreased the soil pH and EC. In tap water irrigated soil, the highest pH and EC reduction (8.06 to 7.40 and 4.01 to 3.34 dS m^{-1}) were observed in T_5 (Soil + *S. portulacastrum* +Vermicompost + Tap water). In tannery effluent irrigated soil, the highest pH and EC reduction (8.06 to 7.56 and 4.01 to 3.50 dS m^{-1}) were observed in T_6 (Soil + *S. portulacastrum* +Vermicompost + Tannery effluent).

S. portulacastrum are capable to decrease the soil electrical conductivity by absorbing soluble salts mainly sodium ions. Moreover, electrical conductivity is the most common measure of soil salinity and indicative of the ability of an aqueous solution to carry an electric current (Ravindran *et al*., 2007).

Sodium content of soil sample

Simultaneous reduction in sodium content of soil during the cultivation period of plant. However maximum reduction was observed at 90 days. The highest reduction of sodium in tap water irrigated soil (652 to 551 mg kg^{-1}) was observed in T_5 (Soil + *S. portulacastrum* +Vermicompost + Tap water). The highest reduction of sodium in tannery effluent irrigated soil (652 to 572 mg kg^{-1}) was observed in T_6 (Soil + *S. portulacastrum* +Vermicompost + Tannery effluent).

Rabhi *et al*. (2011) also observed that, in *S. portulacastrum* cultivated soil, the soluble Na^+ concentration decreased from 1.4 to 0.9 mg g^{-1}. Salt tolerant plants would be better adapted to copping with environmental stresses including heavy metals. Ayyappan *et al*. (2016) also documented that the accumulation of sodium was found in *S. portulacastrum.* The declination of ions in soil helps in reclamation of salt-affected soils. (Yildiztugay *et al*., 2014).

Chromium content of soil sample

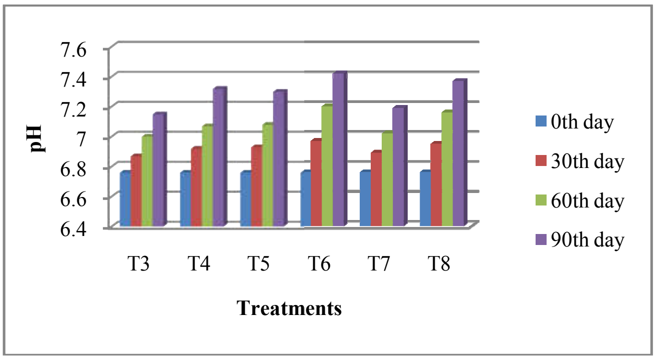
The accumulation of chromium content in *S. portulacastrum* cultivated soil was gradually declined. Maximum reduction was observed at 90 days after planting. The highest chromium reduction in tap water irrigated soil (482 to 435 mg kg^{-1}) was observed in T_5 (Soil + *S. portulacastrum* +Vermicompost + Tap water) and the highest chromium reduction in tannery effluent irrigated soil (482 to 453 mg kg^{-1}) was observed in T_6 (Soil + *S. portulacastrum* +Vermicompost + Tannery effluent). Ayyappan *et al*. (2016) stated that the maximum bioaccumulation of chromium, cadmium, copper and zinc content was observed in *S. portulacastrum* cultivated in the tannery effluent treated soil and also, Gurmeet *et al*. (2007) observed that the application of organic amendments like vermicompost and FYM, declined the Cr concentration.

The results of the present study showed a gradual decrease of chromium in the soil from 0 to 90 days after planting. This was mainly due to the uptake of the metal from the contaminated soil which leads to the accumulation of the metal by the plant and there by declining the effect of salt and heavy metal in soil through phytormediation by *S. protulacastrum*.

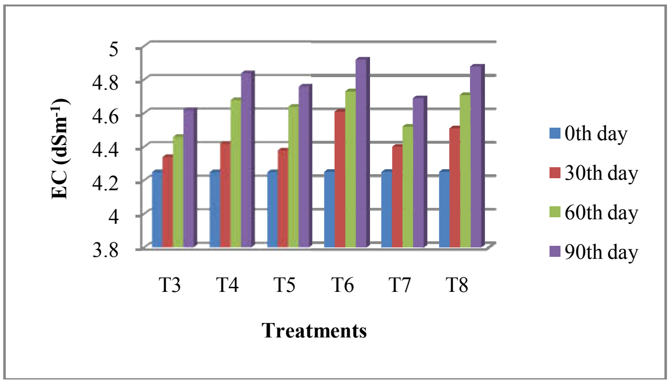
pH and EC of plant sample

Correspondingly pH and EC were increased in *Sesuvium portulacastrum* (Graph 1 and 2). The treatment with tannery effluent contaminated soil + *S. portulacastrum* + vermicompost + tap water (T_5) showed highest pH and EC (6.76 to 7.30 and 4.25 to 4.76 dS m^{-1}). In the tannery effluent irrigated plants, highest pH and EC (6.76 to 7.42 and 4.25 to 4.92 dS m^{-1}) were observed in the treatment with tannery effluent contaminated soil + *S. portulacastrum* + vermicompost + Tannery effluent irrigated (T_6).

The obtained results were similar to the work documented by Rabhi *et al*. (2009) stated that *S. portulacastrum* seedlings grown on a saline soil significantly reduced the soil pH and EC by absorbing soluble salts mainly sodium ions and they also reported that *S. portulacastrum* was able to accumulate nearly 30 per cent of Na^+ content in shoot and reported that *S. portulacastrum*, an obligate halophyte, decrease the soil salinity and sodicity.



Graph 1 pH of *S. Portulacastrum* grown in tannery effluent contaminated soil



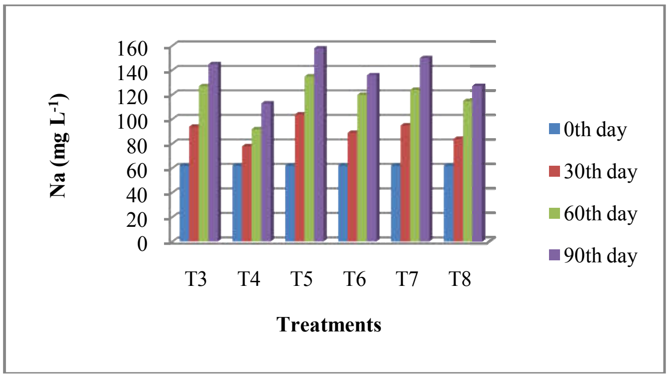
Graph 2 EC of *S. portulacastrum* grown in tannery effluent contaminated soil

Sodium content of plant samples

Graph 3 shows the accumulation of sodium content in *Sesuvium portulacastrum*. The highest accumulation of sodium in tap water irrigated plants (62 to 158 mg kg^{-1}) was observed in T_5 (Soil + *S. portulacastrum* +Vermicompost + Tap water). The highest accumulation of sodium in tannery effluent irrigated plants (62 to 136 mg kg^{-1}) was noticed in T_6 (Soil + *S. portulacastrum* +Vermicompost + Tannery effluent).

Ramesh *et al.* (2009) reported that *S. Portulacastrum* could remove about 968 kg of sodium chloride from one hectare land. *S. portulacastrum* can be used for phytoremediation of tannery wastewater treated soils and a detailed study on the accumulation of Na^+ by the plant with respect to climatic variations and influence of soil conditions was documented. Ghnaya *et al.* (2007) reported that *S. portulacastrum* have the ability of reclamation of salt-affected soils.

The salt tolerant plants (*S. portulacastrum*) would be better adapted to copping with environmental stresses including heavy metals. Ayyappan *et al.* (2016) also stated that bioaccumulation of sodium was found in *S.portulacastrum* and on the other hand, these ions drastically declined in soil and increased in the plants.

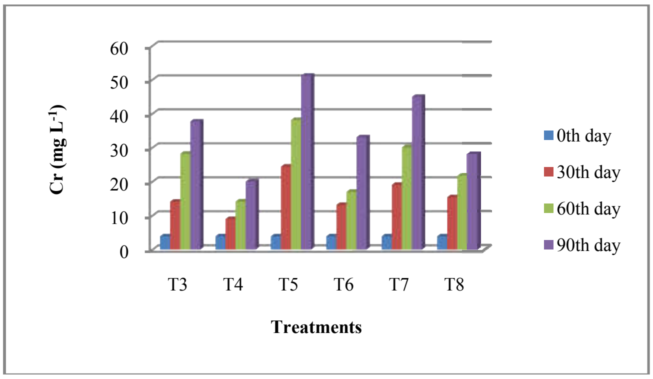


Graph 3 Accumulation of Na in *S. portulacastrum* grown in tannery effluent contaminated soil

Chromium content of plant sample

The highest chromium accumulation in tap water irrigated plants (4.01 to 51.25 mg kg^{-1}) was observed in T_5 (Soil + *S. portulacastrum* +Vermicompost + Tap water) and the highest chromium accumulation in tannery effluent irrigated plants (4.01 to 33.15 mg kg^{-1}) was observed in T_6 (Soil + *S. portulacastrum* +Vermicompost + Tannery effluent) (Graph. 4).

The obtained results were similar to the work documented by Ayyappan *et al.* (2016) that simultaneous increase in heavymetal in plant sample and also the reduction in soil was observed in tannery effluent treated soil throughout the cultivation period of *S. portulacastrum*. It had the potential of tolerance against a variety of toxic heavy metals and capacity to uptake the heavy metals even at higher concentrations (Patil *et al*., 2012).Therefore, it was hypothesized that *S. portulacastrum* have adaptive properties to tolerate the external presence or accumulation of heavy metals like Cr within their tissues (Lutts and Lefevre, 2015).

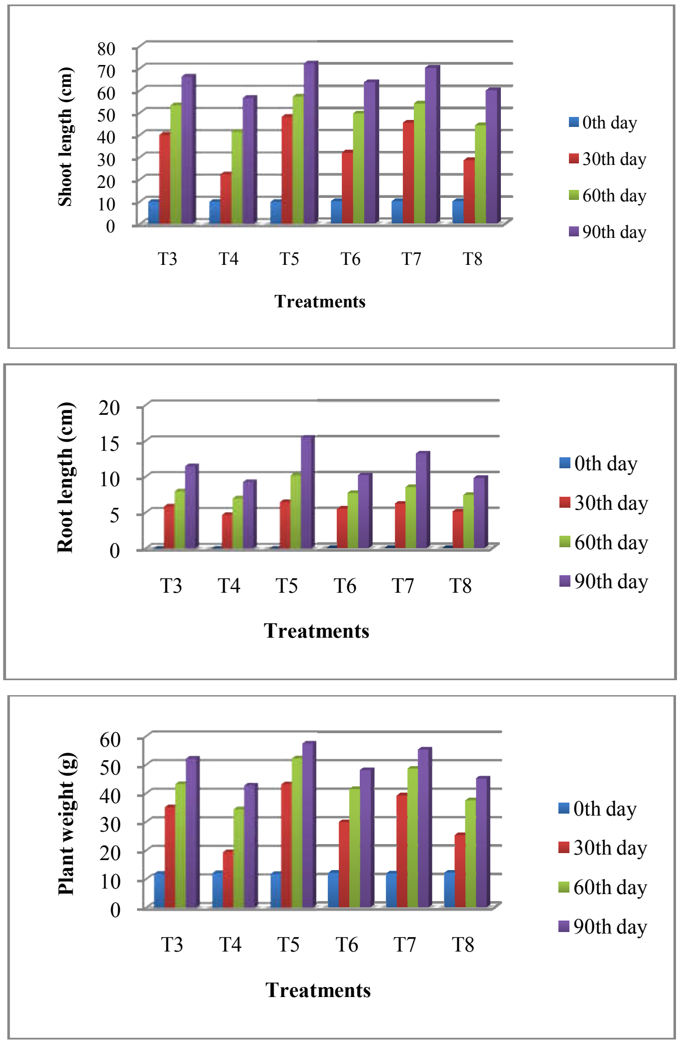


Graph 4 Accumulation of Cr in *S. portulacastrum* grown in tannery effluent contaminated soil

Biometric observations of S. portulacastrum grown in tannery effluent contaminated soil

The observation on growth parameters shows the significant index on morphological growth attributes of *S. portulacastrum.* In tap water irrigated plants, the highest mean shoot length (47.0 cm), root length (10.7 cm) and plant weight (51.00 g) was recorded in T_5. In effluent irrigated plants, the highest mean shoot length (38.8 cm), root length (7.8 cm) and plant weight (39.80 g) was recorded in T_6(plate 1. 2, 3 and 4) (Graph 5).

The gradual increase in plant growth at 0 to 90 days after planting was evident in the present study which was also reported by Rajaravindran and Natrajan (2012). The present study shows that increase in shoot length, root length and plant weight in addition of organic amendments like vermicompost and farmyard manure. Similar results were also reported by Ravindran *et al.* (2007).



Graph 5 Biometric observation of *S. portulacastrum* grown in tannery effluent contaminated soil

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