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EVALUATING THE PHYTOREMEDIATION POTENTIAL OF *ATRIPLEX PATULA* ON SALT CONTAMINATED SOIL

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Abstract

Phytoremediation is an environmentally-friendly technique that is gaining importance in restoring contaminated soils. This paper presents the results of a laboratory experiment designed to evaluate the phytoremediation potential of *Atriplex patula* grown in salt contaminated soil.

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Atriplex patula was grown in pots instrumented with TDR-miniprobes that have the capability to monitor water and salt movement within the root zone. As the salt contaminated soil did not support plant growth, a 1:1 mixture of contaminated soil and peat moss was used. A destructive analysis of the plants and different layers of soil revealed the changes in chemical composition after 150 days of growth.

Analysis of plant foliage showed accumulation of Cl^- and Na^+ in leaves and stems. Chemical composition of different soil layers revealed that *Atriplex patula* could tolerate excessive levels of salt contamination and grow without showing any apparent effect on its growth. Therefore, *Atriplex patula* can be used for revegetation of a salt contaminated soil.

INTRODUCTION

Phytoremediation is a broad term that encompasses the utilization of higher plants to remediate a contaminated medium. In this paper phytoremediation refers to the technique of using vascular plants for removal of contaminants from soil. Phytoremediation has been used as a means of managing wastes, especially petroleum hydrocarbons, polycyclic aromatic hydrocarbon, explosives, organic matter, and nutrients. A number of plants that have the potential of removing soil contaminants have been identified. Research is being carried out to identify plants that have the potential to remove other contaminants that are not currently phytoremediated. This paper looks at the possibility of using *Atriplex patula* plants in removing salt contaminants from a brine contaminated soil.

There are several reasons for salinization of soils. One of the important industrial contributions in severe salinity problem is from the oil industry. In the oil exploration sites, oil is pumped from deep geological formations along with brine that is rich in salts. After separation of the oil from the brine, any accidental spill of the brine can lead to the soil becoming saline and sodic. Various techniques can be used to remediate salt contaminated soils. Leaching out the salts is hampered if the soil is sodic and as a result has a reduced permeability. Using electromigration technique requires buffering the surroundings of electrodes for pH. There is a need to identify remediation techniques that are environment friendly. Phytoremediation is one such technique that needs to be explored.

Halophytes are plants that can tolerate and grow on soils having high salt concentration. They show various physiological adaptations that enable them to grow under high salinity conditions. While growing on salt contaminated soils some halophytes are known to accumulate salts in plant parts. *Atriplex patula* is an example of halophyte which accumulates salts. A number of researchers have investigated *Atriplex* species in the recent past to look at their potential in removing contaminants and reclaiming soils. Brown et al. (1999) showed that *Atriplex barclayana* could be used as a biofilter to remove nutrients from saline aquaculture effluents. Slavich et al. (1999) planted *Atriplex nummularia* as a vegetative cover in a salt affected land in southeast Australia. However, low transpiration rate (0.3 mm/d) of these plants had little hydrologic effect on the shallow water table. In laboratory experiments, Khan et al. (2000) showed that *Atriplex griffithii* variety *stocksii* grown in pots with varying concentrations of NaCl had high Na^+ and Cl^- content in plant parts and the ash content increased to 39% of the dry weight in leaves. In a field experiment Chisci et al. (2001) demonstrated the use of *Atriplex halymus* L. in improving physical characteristics of a clay soil in Italy. Vikerman et al. (2002) evaluated thirty *Atriplex* lines for potential habitat improvement and phytoremediation of selenium contaminated sites. *Atriplex patula* was found to be one of the top selenium accumulators and grew well in saline soil.

A site located in the Turtle Mountain Provincial Park in Southwestern Manitoba was found to have highly saline and sodic soil resulting from an abandoned oil production site.

Because the site is located in a Park environment, it was decided to use an environmentally-friendly technique such as phytoremediation to reduce the salt levels. A survey done in the Park area identified various halophytes that already exist in the Park area. Germination trials conducted with salt-contaminated soil showed varying degrees of success. *Atriplex patula* was one of the plants that succeeded in the germination trial. There is a need to investigate the salt-contaminant removal potential of *Atriplex patiula*. Therefore, the objective of this study was to estimate the salt contaminant removal potential of *Atriplex patula*. A further emphasis in this study was to closely monitor the changes in salt contamination within the rootzone as a function of depth and stage of growth.

MATERIALS AND METHODS

Atriplex patula was grown in three pots (replicates) instrumented with TDR mini-probes that have the capability to monitor water and salt movement within the root zone. As the salt contaminated soil did not support plant growth, a 1:1 mixture of contaminated soil and peat moss was used. The plants were established by direct seeding into the pots. The plants were watered daily and the apparent electrical conductivity and water content were also measured on a daily basis. The seeds started germinating by the 6th day. The amount of water added to the plants was increased from 100 mL to 150 mL per pot after 24 days. The plants were harvested on the 150^{th} day. The plants had an average height of 45 cm. The plant samples were analyzed for various salt components. The potted soil was sliced into four 5-cm sections horizontally to do a destructive analysis of the salt contents. The TDR measurements within the rootzone at different layers of soil revealed the changes in chemical composition occurring during the 150 days of growth.

An attempt also was made to grow Atriplex patula under poorly drained conditions as well. The plants grew in pots with no drainage. However, the plants were smaller compared to those grown in the other experiment.

RESULTS AND DISCUSSION

Table 1 presents the concentrations of salt contaminants in the contaminated soil and the contaminated soil mixed with peat moss on a 1:1 weight basis. The contaminated soil has extremely high concentration of chloride and sodium ions. The sodium adsorption ratio was 74.3. The electrical conductivity was 145 dS/m. Therefore, the contaminated soil is a highly saline and sodic soil. Because of the high salt content, peat moss was added to reduce the salt content and make it more suitable for germination. As shown in Table 1 the chloride and sodium concentrations were reduced to nearly half of their original concentrations. The sodium adsorption ratio was brought down to 34.4. The electrical conductivity was reduced to 48 dS/m.

Table 1. Salt contaminant concentrations in the contaminated soil and the contaminated soil mixed with peatmoss on a 1:1 basis.

Components	**Contaminated Soil(mg/kg)**	**Contaminated Soil + Peatmoss (mg/kg)**
Oil and Grease	5800.0	4750.0
Calcium	3335.0	2550.0
Magnesium	1580.0	903.0
Sodium	17950.0	8470.0
Potassium	175.0	135.0
Chloride	37350.0	17400.0
Sulfate-S	670.0	694.5

After 150 days of plant growth, plants were harvested and analyzed for salt components. Table 2 gives the plant dry matter for each pot and some of the salt components determined in the foliage of the plants in each pot. The mean plant dry matter yield was 16.15 g per pot. The mean amount of chloride and sodium removed were 1.55 and 0.38 g per pot, respectively. Therefore, on a per soil volume basis, 0.25 kg/m^3 Cl^- and 0.06 kg/m^3 Na^+ were removed by the aerial parts of the *Atriplex patula*. Assuming a root zone depth of 0.2 m, 0.049 kg/m^2 Cl^- and 0.012 kg/m^2 Na^+ were removed by *Atriplex patula* on an area basis.

Table 2. Plant dry matter and amounts of salt components removed by *Atriplex patula*

Plant dry matter (g)	Chloride (g)	Sodium (g)	Magnesium (g)	Sulfate-S (g)
17.24 (21 plants/pot)	1.79	0.431	0.102	0.034
15.32 (17 plants/pot)	1.36	0.332	0.084	0.023
15.91 (9 plants/pot)	1.50	0.364	0.092	0.025
Mean	**1.55**	**0.376**	**0.093**	**0.027**

Electrical conductivity Figure 1 shows the changes in electrical conductivity as a function of depth. The solid line in the graph refers to the initial electrical conductivity (48 dS/m) of the soil solution. The increase in electrical conductivity with depth was attributed to salt leaching to deeper layers. Healthy growth of *Atriplex patula* in a soil with relatively high electrical conductivity is an indication of its tolerance for high salt content.

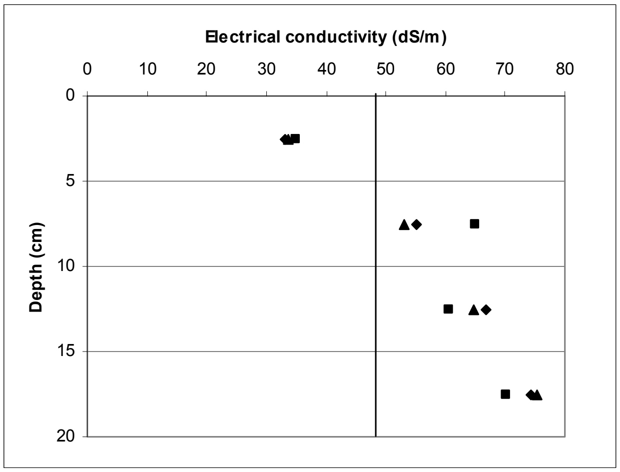

Fig. 1. Electrical conductivity as a function of soil depth in the pots grown with *Atriplex patula*. Data points are from three replicates. The solid vertical line refers to the electrical conductivity of the contaminated soil mixed with the peat moss.

Sodium Adsorption Ratio Sodium Adsorption Ratio increased as a function of depth and was attributed to the downward movement of salt by leaching. The solid line in the graph refers to the initial SAR of 34%. Healthy growth of *Atriplex patula* in this highly sodic soil is indicative of its tolerance for high salt content.

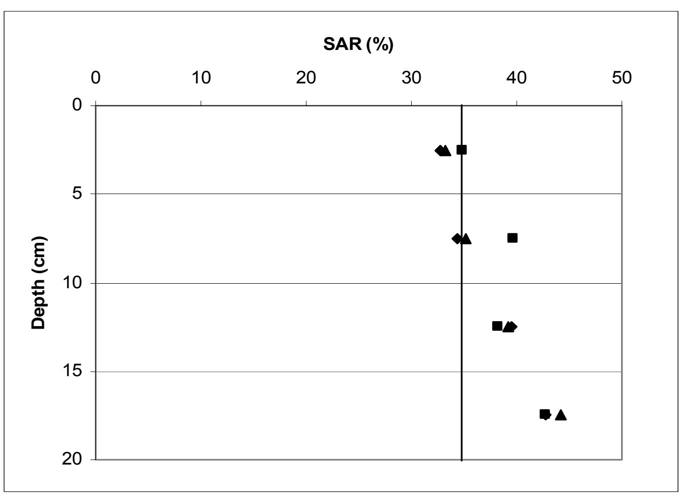

Fig. 2. Sodium Adsorption Ratio (SAR) as a function of soil depth in the pots grown with *Atriplex patula*. Data points are from three replicates. The solid vertical line refers to the SAR of the contaminated soil mixed with the peatmoss.

Chloride content Figure 3 shows the chloride content changes in the rootzone. The dotted line in the graph refers to chloride content of the original contaminated soil (37.0 g/kg) (prior to mixing with peat moss). The *Atriplex patula* plants grown in such high chloride concentrations shows the tolerance they have for chloride ions.

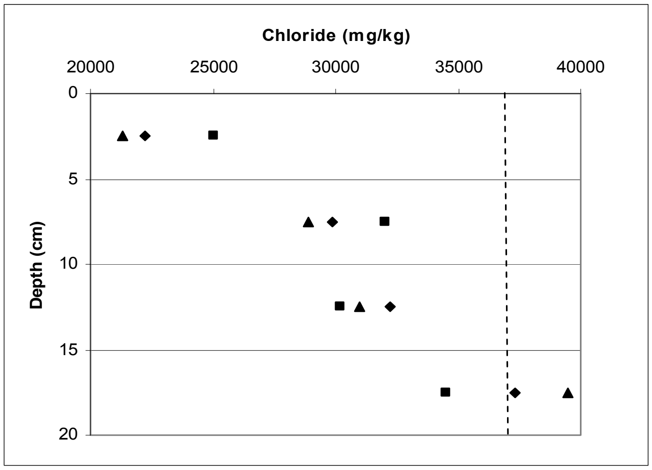

Fig. 3. Chloride concentration as a function of soil depth in the pots grown with *Atriplex patula*. Data points are from three replicates. The dashed vertical line refers to the chloride concentration of the contaminated soil (prior to mixing with peatmoss).

Sodium content Sodium content as a function of depth increased with depth and was attributed to the salt leaching down as shown in Fig. 4. The dotted line in the graph refers to sodium content of the original contaminated soil (17.95 g/kg) (prior to mixing with peat moss). *Atriplex patula* plants have a remarkable ability to grow in a soil with very high sodium content.

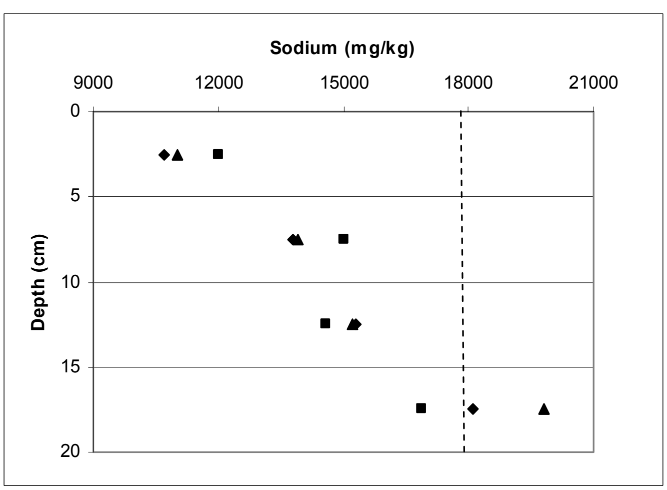

Fig. 4. Sodium concentration as a function of soil depth in the pots grown with *Atriplex patula*. Data points are from three replicates. The dashed vertical line refers to the sodium concentration of the contaminated soil (prior to mixing with peat moss).

Magnesium content Figure 5 shows the variation of magnesium concentration as a function of soil depth. The dotted line in the graph refers to magnesium content of the original contaminated soil (1.58 g/kg) (prior to mixing with peat moss). Magnesium content at the deepest layer was much higher than that of the original contaminated soil.

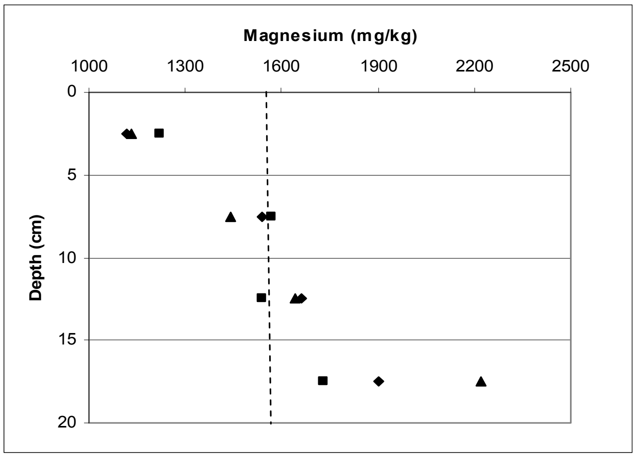

Fig. 5. Magnesium concentration as a function of soil depth in the pots grown with *Atriplex patula*. Data points are from three replicates. The dashed vertical line refers to the magnesium concentration of the contaminated soil (prior to mixing with peat moss).

Sulfate-S content Figure 6 presents the changes sulfate-s concentrations as a function of depth. The dotted line in the graph refers to sulfate-S content of the original contaminated soil (670 mg/kg) (prior to mixing with peatmoss). Sulfate-S content characteristically remained at the same level except in the first 5cm soil layer. The sulfate-S contents in the deeper layers were considerably higher than that of the contaminated soil.

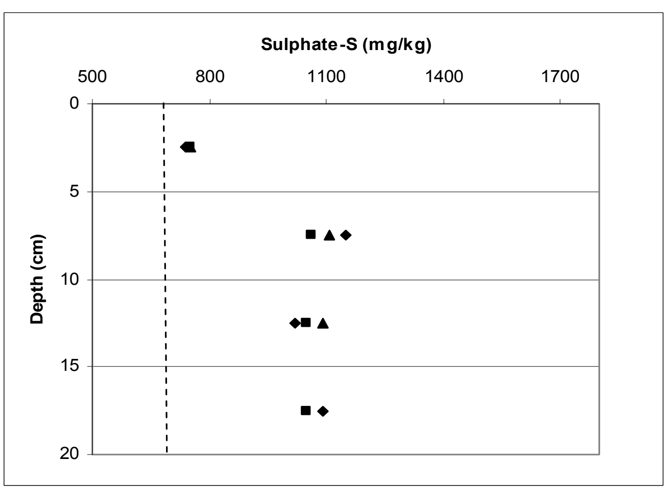

Fig. 6. Sulfate-S concentration as a function of soil depth in the pots grown with *Atriplex patula*. Data points are from three replicates. The dashed vertical line refers to the Sufate-S concentration of the contaminated soil (prior to mixing with peatmoss).

CONCLUSIONS

Atriplex patula grew well in salt contaminated soil mixed with peatmoss on a 1:1 weight basis. The *Atriplex patula* has the potential to remove 0.25 kg/m^3 Cl^- and 0.06 kg/m^3 Na^+ from the salt contaminated soil over a period of 150 days. The destructive analysis of different layers of the soil indicated that salt contaminants were leached down to deeper soil layers. The concentrations of salt contaminants at the deepest soil layer were closer to or greater than those of the salt contaminated soil. Despite these high salt concentrations at the deepest soil layer, Atriplex patula plants showed a healthy growth. This can be attributed to the reduced contaminant concentrations at the upper layers of the soil which was more conducive during the germination stage. Atriplex patula can be established even under poorly drained conditions.

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