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Potentiality of *Suaeda monoica* Forsk. A Salt Marsh Halophyte on Restoration of Saline Agricultural Soil

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Abstract: Coastal area agricultural soils are generally characterized by the presence of sodium and chloride which results in poor physiological properties and fertility of the soil. Reclamation of saline soil was carried out by different methods such as physical, chemical, electro and hydro technical amelioration. In recent years phytoremediation has shown promise for the restoration of saline-sodic soil. Here we shall review the feasibility of *Suaeda monoica* on salt bioaccumulation. From the results it was concluded that *Suaeda monoica* showed positive growth and greater accumulation of salts in their tissues and higher reduction of salts from the soil. EC which was initially 5.1dSm^{-1} in the soil significantly reduced to 1.8dSm^{-1} after 120 days of cultivation. Correspondingly EC was increased from 3.9dSm^{-1} to 18.8dSm^{-1} in plant sample, showed reduction of salts in the field. It was estimated that *Suaeda monoica* could removed 453.55kg sodium chloride in the soil from one hectare land in four month time. *Suaeda monoica* could therefore be used successfully to reclaim salt affected agricultural lands and rendering them more suitable for crop production after few repeated cultivation.

Key words: Salinity · Restoration · Halophytes · Phytoremediation

INTRODUCTION

Soil degradation resulting from salinity or sodicity is a major environmental constraint with severe negative impacts on agricultural productivity and sustainability, particularly in arid and semiarid regions of the world [1]. However, salinity is not inimical to all plants. Halophytes are plants that can survive on high concentrations of salt in the rhizosphere and grow well [2]. The distribution and exploitation [3] and physiology of salt tolerance [4-6] of halophytes are intensively studied. Moreover, the leaf tissues of halophytes are adapted to accumulate large amounts of saline ions. Such adaptive mechanism is crucial to generate a water potential gradient along root-shoot to maintain water flux throughout plants [7].

Several halophytic plant species has been tried in past for their possible use in reclamation of salt affected soils [8-11]. After conducting number of experiments, several researchers found phytoremediation to be an effective amelioration strategy for saline-sodic soils with comparable performance against the use of chemical amendments [12-14].

The objective of the present study is to utilize salt accumulating halophyte *Suaeda monoica* Forsk. to assess the feasibility of salt bio accumulation for restoration of salt affected agricultural lands as an alternative method to other leaching techniques.

MATERIALS AND METHODS

Experimental Site for Reclamation Studies: The experimental site (Salt affected agricultural land) was located at Thandavarayan Sozhanpettai village nearer to Pichavaram mangrove forest (11° 24^1 N and 79° 44^1 E) on the north east coast of TamilNadu, India. The field experiments were conducted from March 2010 to August 2010. Pichavaram mangrove forest received an average rainfall of 89.4 cm spread over the year. Temperature ranged from a summer maximum of 33.5 to a winter 24.4°C.

Before conducting the experiments, EC, pH and SAR in saline soil was found to maximum 5.1dS m^{-1}, 8.8 and 16.94 respectively. Chloride content was maximum 69.7meq/lit and Sodium was 56.7meq/lit.

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Selection of Species: Fast growing and dominant salt accumulating halophyte *Suaeda monoica* forsk. was selected for restoration studies.

Preparation of Land: The experimental field was ploughed with tractor drawn disc plough followed by a through harrowing to break the clods. The field was properly leveled and 5×10M size plots were earmarked with raised bunds and 30cm spacing between 2 seedlings. The seedlings of *Suaeda monoica* species were raised and planted at the experimental field. Proper care was taken to maintain the plants. Plant samples were harvested for experimental purpose at an intervals of 30, 60, 90 and 120 days.

Morphological Studies

Analysis of Growth Characteristics: The fresh weight was measured immediately after removing the seedlings from the experimental field. The dry weight of the seedlings was determined after they had been dried for 80°C for 24 hours.

Soil Analysis: The soil samples from 0-15 cm depth were collected from the experimental field for soil analysis. These soil samples were dried and powdered gently with wooden wallet and passed through 2 mm sieve. The sieved soil samples were then taken up for analysis. Available soil sodium content was estimated by Stanford and English [15] and Chloride content by Jackson (1973). Soil Electrical Conductivity was estimated by Jackson [16].

Plant Analysis: The mature and fully developed leaves were detached from the twigs and surface dust was washed with distilled water and blotted dry. The mid-ribs were removed and laminae were oven dried at 80°C and ground well and used for acid digestion. The plant sodium content was estimated by Williams and Twine [17] and plant Chloride content was estimated by Krishnamoorthy and Bhagwat [18]. SAR for soil was determined by the method of Richards [19].

Measurement of Ec of the Plant Sample: Five gram of fresh plant samples were ground in mortar and pestle by using water [1:3] and then filtered through cheese cloth. This crude extract was used to determine the EC by using Elico EC meter.

Bioaccumulation of Salts: The quantity of salt removed from the soil is determined based on the formula,

Total accumulation of salt = Biomass accumulated salts/g X Total biomass

Statistical Analysis: The experimental data was processed statistically by adapting the technique of analysis of variance of Standard Deviation [20].

RESULTS AND DISCUSSION

In the present study *Suaeda monoica* developed significant increase in the above ground biomass in salt affected agricultural land when compared to control. Nearly 77.13% (Figure 1) increase in fresh weight and 72.73% (Figure 2) in dry weight was observed in *Suaeda monoica* when compared to control after 120 days of cultivation.This is in accordance with studies in several species that NaCl stimulated the shoot and root growth in *Atriplex patula* [21], *Suaeda fruticosa* [22], *Suaeda salsa* [23] and *Suaeda physophora* [24]. *Salvadora persica* grown at moderate salinity (200 Mm NaCl), induced 100% increase in fresh weight and 30% increase in dry weight when compared to that of non salinized controls [25]. Cherian and Reddy [26] reported in *Suaeda nudiflora*, that higher salinity (340 mol^3 NaCl) increased 214% and 256% fresh and dry weight respectively.

Increase in dry weight may be attributed to the accumulation of inorganic constituents in the plant tissue. *Suaeda fruticosa* plants grown in saline conditions (200 to400 mol M^{-3} NaCl) had more fresh and dry weight than those grown in non-saline control [22]. External NaCl also stimulated fresh and dry weight, number of leaves and leaf area at optimum level of seawater in *Rhizophora mangle* [26]. The increase in fresh weight of halophytes under salinity in the present study can be attributed to the increase in leaf thickness and accumulation of ions and water content could be a good reason for promoted succulence [27].In general, the growth parameters were stimulated in saline soil and it favored maximum growth and increased leaf area [data not shown]. In the present study, the maximum increase in dry weight was observed in *Suaeda monoica* and it was mainly due to accumulation of Na salts as reported earlier in other species of *Suaeda* [28]. However, in control plants (without salt), all these parameters showed a decline, hence it may be concluded that saline soil favored maximum growth and development of *Suaeda monoica* cultivated for restoration studies.

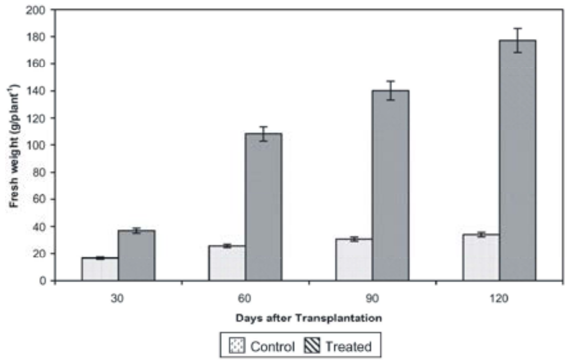

Fig. 1: Fresh weight of *Suaeda monoica* cultivated in salt affected agricultural land. The values shown are means (± SD) of five replicates.

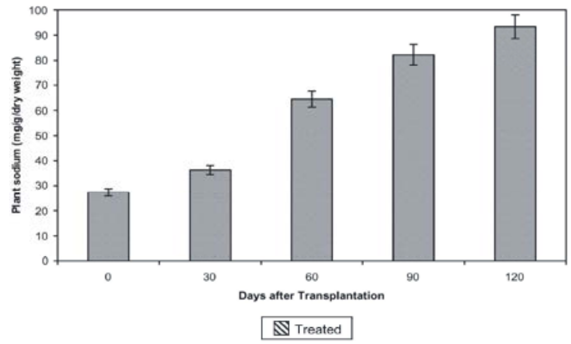

Fig. 4: Sodium content in plant sample of *Suaeda monoica* cultivated salt affected agricultural land. The values shown are means (± SD) of five replicates.

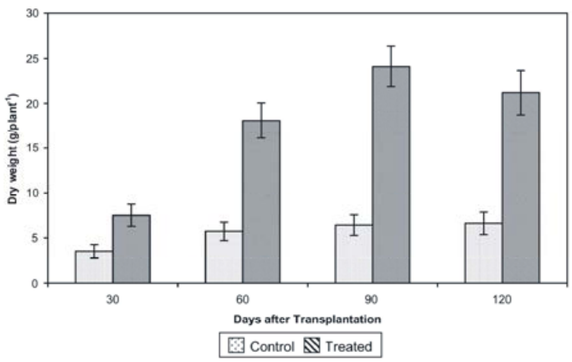

Fig. 2: Dry weight of *Suaeda monoica* cultivated in salt affected agricultural land. The values shown are means (± SD) of five replicates.

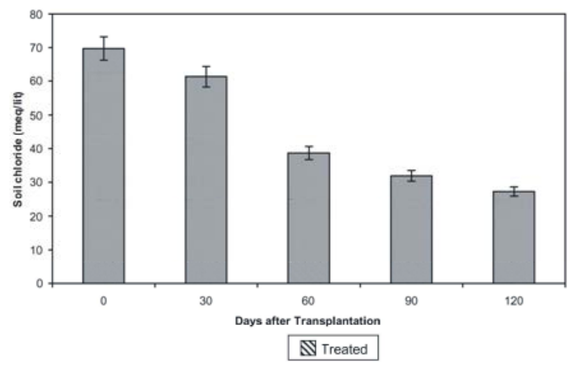

Fig. 5: Chloride content in soil sample of *Suaeda monoica* cultivated salt affected agricultural land. The values shown are means (± SD) of five replicates.

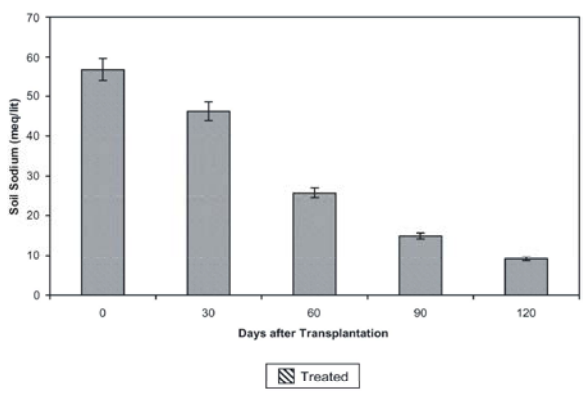

Fig. 3: Sodium content in soil sample of *Suaeda monoica* cultivated salt affected agricultural land. The values shown are means (± SD) of five replicates.

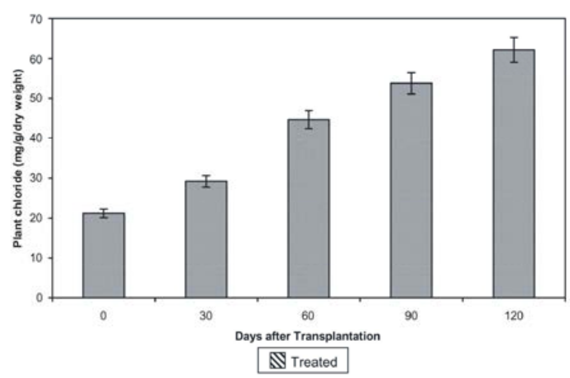

Fig. 6: Chloride content in plant sample of *Suaeda monoica* cultivated salt affected agricultural land. The values shown are means (± SD) of five replicates.

From the results (Figure 3) it was observed that *Suaeda monoica* cultivated in salt affected agricultural land considerably decreased the soil salinity by absorbing high amounts of sodium from the soil. The highest reduction (-83.92%) in sodium content from the soil was observed when compared to control after 120 days of cultivation. Correspondingly, *Suaeda monoica* plants accumulated the highest sodium content (241.85%) (Figur 4). A tendency to accumulate NaCl has been reported for many other halophytes and was associated with salt tolerance [9]. Accumulations of high sodium content in halophytes in the present study are in agreement with those of several other "accumulating type" of halophytes [11, 23, 24, 29]. Cherian and Reddy [26] observed in *Suaeda maritima* that an increase in NaCl concentration gradually, increased Na^+ accumulation and the accumulation was significantly higher in leaves than in shoot or root. Analysis of ion accumulation in *Salvadora persica* revealed that the leaves accumulated Na^+ as a primary osmoticum. The concentration of Na^+ in leaves of salinized plants was approximately 40-fold greater than that measured in non-salinized controls [25]. While Na is not considered to be a plant nutrient, it is essential for halophytes (Salt-loving species) to accumulate salts to maintain their turgor pressure and growth [30].

Results also revealed that chloride content was also reduced in salt affected agricultural land (Figure 5). The maximum reduction in chloride content was observed in *Suaeda monoica* cultivated soil (-60.93%) after 120 days of cultivation. Similar to sodium, the maximum chloride (Figure 6) was accumulated by *Suaeda monoica* (193.44%). Similar results of increase in chloride content have been reported in other halophytes such as *Spergularia marina* [31], *Ipomoea pes-caprae* [32], *Suaeda* species [26], *Portulaca oleraceae* [33], *Suaeda glauca* [34] and *Atriplex halimus* [29]. Niu *et al.* [35] and Blumwald *et al.* [36] have stated that Na and Cl are energetically efficient osmolytes for osmotic adjustment and are compartmentalized into the vacuole to minimize cytotoxicity. Since plant cell growth occurs primarily because of directional expansion mediated by an increase to vacuolar volume, compartmentalization of Na and Cl facilities osmotic adjustment that is essential for cellular development. From the results, it is clearly revealed that *Suaeda monoica* cultivated land considerably decreased the soil salinity by absorbing high amounts of the sodium and chloride from the soil. It is estimated that from 1g dry weight of plant sample *Suaeda monoica* accumulated 155.54 mg of NaCl (Figure 7). From the data it is also calculated that *Suaeda monoica* could accumulated 453.55 kg NaCl from one hectare land in four months time.

From these results, it is calculated that *Suaeda monoica* accumulated larger amount of NaCl in their tissues. In agreement with our results, Gorham *et al.* [37] observed that vascular halophytes accumulated high levels of sodium and other salts in their above ground tissues while others did not. Boyko [38] was the first to suggest that halophytic plants could be used to desalinate soil and water. Bio-remediation studies of

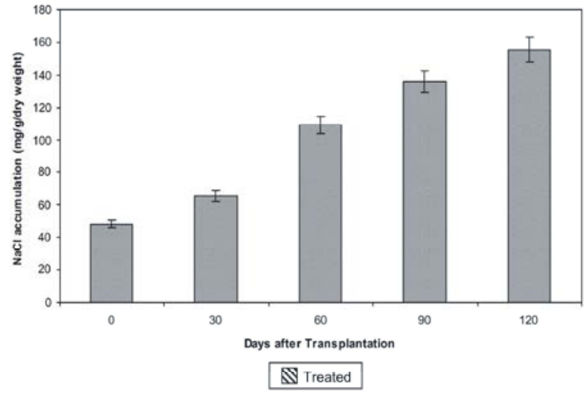

Fig. 7: Accumulation of NaCl in *Suaeda monoica* cultivated in salt affected agricultural land. The values shown are means (± SD) for five replicates.

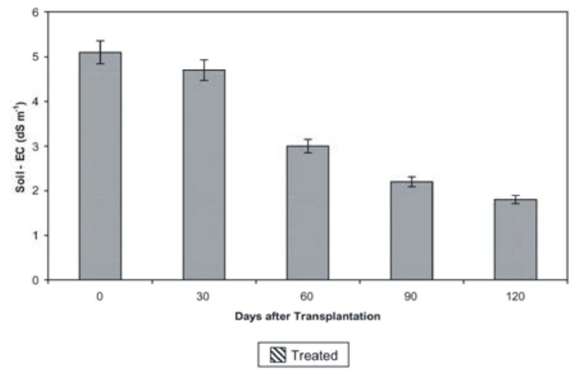

Fig. 8: Soil EC of *Suaeda monoica* cultivated in salt affected agricultural land. The values shown are means (± SD) for five replicates.

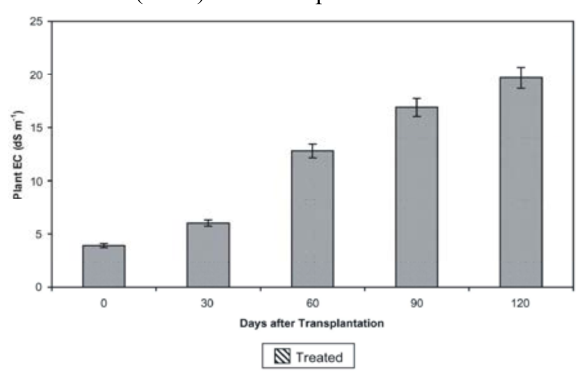

Fig. 9: Plant EC of *Suaeda monoica* cultivated in salt affected agricultural land. The values shown are means (± SD) for five replicates.

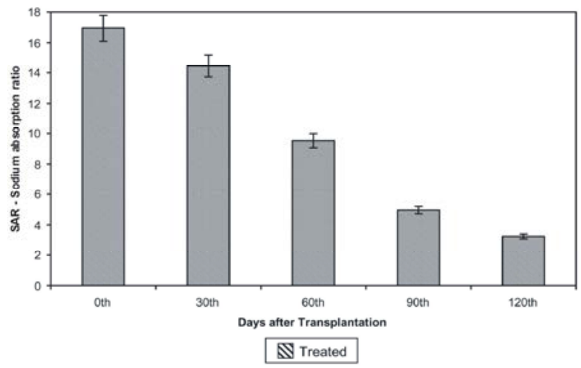

Fig. 10: Sodium absorption ratio of *Suaeda monoica* cultivated in salt affected agricultural land. The values shown are means (± SD) for five replicates.

saline-sodic soil were made in Amshot grass in northern Egypt by Helalia *et al.* [39] and they reported that Amshot grass [*Echinochloa stagninium*] when compared to ponding and gypsum treatment, reduced the exchangeable sodium percent (ESP) of the surface layer of the soil. Holmes [40] successfully used native halophyte plants to reclaim salt contaminated soils in Ohio, Oklahoma and Texas and reported that the content of sodium in the soil was decreased by 65% two years after planting with salt accumulating plants. Ravindran *et al.* [11] observed in *Suaeda maritima* and *Sesuvium portulacastrum* which exhibited greater accumulation of salts in their tissues and higher reduction of salts in the saline land.

Electrical conductivity is the most common measure of soil salinity and is indicative of the ability of an aqueous solution to carry an electric current. In the present study, EC was reduced from 5.1 to 1.8dS/m^{-1} in *Suaeda monoica* cultivated soil (Figure 8) after 120 days of cultivation and correspondingly EC was increased from 3.9 to 18.8dS/m^{-1} in plant samples (Figure 9). Zahran *et al.* [41] observed that *Juncus rigidus* decreased the soil EC from 33 to 22dS m^{-1}. Singh *et al.* [12] conducted a long term field study on an alkaline soil in order to improve such soils by growing P*rosopis julifera* and *Leptocholoa fusca* and they concluded that the soil EC decreased from 2.2 to 0.42 dSm^{-1}.

In the present study, (Figure 10) it is noticed that SAR content gradually declined in salt affected agricultural land where *Suaeda monoica* was cultivated. SAR content was reduced from 16.94 to 3.23 meq/lit (80.9% reduction) in *Suaeda monoica* cultivated land after 120 days of cultivation. Sodium absorption ratio (SAR) is usually a good indicator of the structural ability of soil. In general sodium adsorption ratio is employed to understand the equilibrium relation between soluble and exchangeable cations. Nasir [42] observed that SAR declined from 22.8 to 3.30 and from 25.1 to 3.44 respectively for plots cultivated with *Atriplex hallimus* and *Atriplex nummularia.* Rabhi *et al.* [43] also noticed that sodium absorption ratio decreased from 59 to 39[mmol^{-1}]$^{1/2}$ in *Sesuvium portulacastrum* cultivated lands.

CONCLUSION

In conclusion *Suaeda monoica* plays a vital role in phytodesalination programs. The duration of phytodesalination process depends on soil salinity and sodicity. Repeated cultivation of *Suaeda monoica* is required for removal of salts from the saline land. Further harvested shoots can be utilized for making organic compost.

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