PHYTOREMEDIATION OF SALT-AFFECTED SOILS: A REVIEW OF PROCESSES, APPLICABILITY, AND THE IMPACT ON SOIL HEALTH IN HISAR, HARYANA

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Abstract: **About one-third areas of these problem soils in Haryana are saline and the chlorides and sulphates of sodium, calcium and magnesium are the dominating soluble salts in them (Dahiya and Laura 1988). The existing technologies on farm salinity management that work well include surface and sub-surface drainage. These are basically civil engineering technologies and are costly to install, difficult to maintain and have the problem of saline effluent management. Apart from that, under Indian conditions with fragmented land holdings a wide application of such technology ,various halophytic taxa especially occurring in saline wastelands could be tailored depending upon the magnitude of salinity or site variations or economical utility of the plants and for additional saline soil reclamation. This bioremediation technology involves the repeated cropping (harvestings] of these hyperaccumulators (as has been done in the present investigations as well) until the soils have reached acceptable levels for the farmers to cultivate their regular crops since roo**

Key words: **salinity,phytoremediation**

I. INTRODUCTION

The problems of soil salinity are most widespread in the arid and semi-arid. Soil salinity is also a serious problem in areas where groundwater of high salt content is used for irrigation. The most serious salinity problems are being faced in the irrigated arid and semi-arid regions of the world and it is in these very regions that irrigation is essential to increase agricultural production to satisfy food requirements. However, irrigation is often costly, technically complex and requires skilled management. Failure to apply efficient principles of water management may result in wastage of water through seepage; over-watering and inadequate drainage result in water logging and salinity problems which reduce the soil productivity, eventually leading to loss of cultivable land. Contaminated soils and waters pose a major environmental problem which may be partially solved by the emerging phytoremediation technology. This cost-effective plant-based approach to remediation takes advantage of the remarkable ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues. . In recent years, knowledge of the physiological and molecular mechanisms of phytoremediation began to emerge together with biological and engineering strategies designed to optimize and improve phytoremediation. In addition

A. STUDY AREA:

Hisar, the west central most district of Haryana State with a total geographical area of 3983.00 sq. km is lies between the North latitudes 28o56’00”: 29o38’30” and East longitudes 75o 21’12”: 76o18’12”. The district is under control of Hisar division and administratively divided into nine community development blocks namely Agroha, Adampur, Barwala, Bass (Hansi-II), Hansi-I, Hisar-I, Hisar-II, Narnaund, and Uklana Mandi. The district has 05 towns namely Hisar, Hansi, Narnaund, Barwala and Uklana and 269 villages.

The district area falls in Yamuna sub-basin of Ganga basin. There is no natural drainage in the district area. However, the area is drained by network of canals and the artificial drains (field drains/channels). These artificial drains are mainly confined in Bass, Hansi-I, Narnaund and Barwala blocks. There are a total of 39 drains existing in the area, which run for a distance of 126.25. Water logging (water level < 2 m bgl) and prone to water logging (water level between 2 and 3 mbgl) conditions exists in the district covering part of Bass (Hansi-II), Hansi-I and Barwala blocks. The water logged area accounts for 37.65 sq km (0.93 %) of the total district area during Pre-monsoon and 264.55 sq km (6.55 %) during post-monsoon period. However, the area under water logging conditions increases almost 7 fold in post monsoon period.

B. ECOPHYSIOLOGY OF NATIVE FLORA OF SALINE WASTELANDS THROWS LIGHT ON THEIR FURTHER SUITABLE CHARACTERIZATION FOR PHYTOREMEDIATION OF SOIL SALINITY

Extensive surveys of fallow saline: lands of Haryana Agricultural University, wild area west of sector 14 and behind CIRB, Hisar and other saline areas in adjoining area Bass,Hasi 1,Hasi2,Ulkana,were made and collected, identified and inventories as ThirtyTwo plant species. The analyses of both plant growth and their rhizospheric soil clearly indicated that Suaeda fruticosa, Aerva tomentosa, Prosopis longlfolia, Salsola baruosma, Portulaea , oleracea, Trianthema portulacastrum, Suaeda nudiflora, Calotropis pracera, Atriplex nummularia, Atriplex lentiformis, Atriplex amnicola, Acacia colei, Arundo donax, Solanum xanihocarpum, Heliotropium ramossimum, Acacia ampliceps, Acacia nilotica, Salvadoran persica, Setaria glauca and Saccharum munja were potential salt hyperaccumulator plants belonging to families Portulacaceae, Aizoaceae Compositae Salvadoraceae Asclepiadaceae, Solanaceae, Amaranthaceae, Chenopodiaceae and Poaceae .

The problem of water logging and soil salinity can be effectively countered by a drainage system which in effect means removal of excess of water, and the salts dissolved in it, from the crop root zone. Three kinds of drainage designated as surface drainage, vertical drainage and horizontal sub-surface drainage have been adopted (Garg and Gupta 1997). Surface drainage refers to the technique of removing excess water from the soil surface in time to prevent damage to crops and to keep water from pounding on the surface (ASAE 1979). The term surface drainage applies to situations where overland flow is the major component of the excess and involves water movement to major drains or natural streams. The technique normally involves the excavation of open trenches/drains. Under monsoon Climate, surface water logging is common and, hence, surface drainage has a considerable relevance in India.

C. IDENTIFICATION AND CHARACTERIZATION OF FLORAS NATIVE TO SALINE SOILS

The word halophyte means ‘salt plant’ as such but this term is used for plants that can grown in the presence of high concentration of salts particularly chlorides and sulphates of sodium (Garg and Gupta 1997). Jennings (1976) adopted the ecological definition and defined halophytes as ‘the native flora of saline soils’.

Zahran (1982) surveyed halophytic vegetation of Egypt and concluded that 90% of these plants are not only highly tolerant to saline soils but also to arid climate. Most (61%) of the succulent halophytes (Halocnemum strobilaceum, Arthrocnemum glaucum, Salicornia fruticosa, Suaeda fruticosa, S. vermiculata and Zygophyllum album), 46% of the excretive halophytes (Limonium pruinosum, Aelurops spp., Sporobolus spicatus, Nitraria retusa, Tamarix mannifera and Cressa cretica) and 45% of the cumulatives (Typha domengenesie, Pharaqmites auetralis, Juncas rigidus, Imperata cylindrical, Scirpus litoralis, Cyperus laeuiqatus and Alhagt maurorum) are widely distributed and dominated in the inland salt marshes and in both the Red Sea and Mediterranean littoral salt marshes of Egypt.

In recent years considerable research efforts have been made in the use of plants to remove inorganic and organic contaminants from the soil by the technique of phytoremediation Chaney et al. 1997, Salt et al., 1998). Phytoremediation is visualized as a benign and cost effective plant based technology that depends upon the remarkable ability of some plants to remove or tralize various chemicals (organics and metal ions) from the soil, water and air (Chaney et al. 1997). Phytoremediation can be used to bioremediate contaminated soil, water and air. It is very cost effective, non invasive and publicly acceptable way to redress the removal of environmental contaminants.

Where drainage effluent is reused for irrigation, salts are redistributed in the land and if it is disposed into the river systems, they get polluted. Where ground water is of poor quality, the problem of water logging becomes more complex as this water cannot be used for irrigation. In view of the aforementioned problems 'green' and benign technologies. I.e. phytoremediation for salinity control (Robinson et al. 1980, Yurtseven and Baran 2000) and biodrainage for both salinity and water table control. (Bell 1999, Ram and Garg 2002, Angrish et al. 2006, Ram et al. 2006) are emerging as alternative means. These are expected to complement or even replace the conventional drainage/salinity management techniques. Relevant aspects of phytoremediation based salinity remediation are discussed el on Indian desert halophytes like, Haloxylon recurvum, H. salicornicum, Portulaca oleracea; Salsola baryosma, Sesuuium sesuuioides, Suaeda fruticosa, Trianthema triquetra, Zygophyllum simplex, etc. leading to thickening in leaves, elongation of cells, higher elasticity of cell walls and smaller relative surface area, decrease in extensive growth, and high water content per unit of surface area. Leaves in some succulent halophytes like those in S. fruticosa, S. baryosma and T. triquetra are reduced in surface area, when exposed to a high salt content in the soil. The third type of plant is known as the, cumulative halophyte which lacks any regulatory mechanism. The salt concentration therefore rises during the growing season and, when a certain level is reached, the plant dies. In the Indian arid zone the main cumulative halophytes are: Faqonia cretica Vernonia cinerea, Eclipta prostrata, Scirpus spp., Cupenis indicator parameter like ash content and TDS of stem and leaves in general, increased

II. RESULT

The present **study "Efficacy of some salt hyperaccumulatmg plants for salinity phytoremediation"** is a preliminary attempt in this direction. For this sets of experiments were conducted. In the first experiment native flora of five saline locations of Hisar ,Haryana was characterized for their salt hyperaccumulation characteristics vis-a-vis rhizospheric soil salinity.

1. In the first ecophysiological characterization experiment a total of 44 plant species belonging to sixteen families of Angiosperms were collected from saline wastelands of five locations in Haryana and Rajasthan. Majority (10) of these plants belonged to the family Chenopodiaceae, followed, by Mimosaceae (4), Poaceae (4), Solanaceae (2), Amaranthaceae (2), and one each to Portulacaceae and Asclepiadaceae.
2. The ECe of the rhizospheric soils of the different locations varied from 5.19 to 60.80. Higher soil Cl^- as compared to, SO_4^{2-} indicated the presence of Cl dominating salinity in all the five locations. pH data of various locations indicated that the soil varied, from neutral to slightly alkaline in nature.
3. The maximum fresh biomass per unit area was accumulated in plant species like Salsola baryosma, Suaeda fruticosa, Suaeda nudijlora and Saccharum munja. On the basis of their shoot, particularly leaf, mineral Ion [Na^+, K^+, Ca^{2+}, Mg^{2+}, CI^-, SO_4^{2-}) composition characteristics twenty species i.e. Achyranthes aspera, Aerva tomentosa, Aeluropus lagopoides, Arundo donax, Atriplex amnicola, Atriplex lentiformis, Atriplex nummularia Calotropis, procera, Chenopodium album, Chenopodium ambrosoides, Chenopodium murale, Heliotropium ramosstmum, Parkinsonia aculeata, Portulaca oleracea, Salsola baryosma, Setaria glauca, Suaeda fruticosa, Suaeda nudijlora, Trianthema portulacastrum and Xanthium strumarium were found promising.
4. Salt hyperaccurnulation with increasing level of salinity in all the experimental plants. The ash content of stem and leaves was found maximum in species

like Achyranthes aspera, Atriplex amnicola, Atriplex lentiformis, Heliotropium ramoesunum, Portulaca oleracea, Salsola baryosma, Suaeda fruticosa and Trianthema portulacastrum and least in Chenopodium species and Arundo donax. Again the TDS of stem and leaves was highest in Suaeda nudiflora, Suaeda fruticosa, Atriplex amnicola, Atriplex lentiformis and Trianihema portulacasirum.

5. Total phytoaccumulation of different ions per pot [Na^+, K^+ Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}) in the above ground biorriass was also enhanced with increasing level of salinity from 0 to 16 dSm^{-1}. It was found maximum in species like Atriplex amnicola, Suaeda nudiflora and Salsola baryosma followed by Suaeda fruticosa, Trianthema portulacastrum, Atriplex leniiformis, Arundo donax and Aerva tomentosa. Whereas the least was found in case of Chenopodium ambrosoides, Aeluropus lagopoides and Setaria glauca.

6. It was observed that the pH, ECe, SAR and different soil ionic contents like Na^+, K^+ Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and total amount of ions declined in the soil after plantation and harvesting of different plant species. The maximum depletion in the mean ionic content and ECe in the soil was observed by the plant species like Suaeda species, Atriplex species and Salsola baruosma.

7. It was estimated that the best salt hyperaccumulator plants were Suaeda nudiflora, Portulaca oleracea, Suaeda fruticosa, Atriplex amnicola, Salsola baryosma and Atriplex leniiformis on the basis of phytoaccumulation of salt ions in their biomass at 16 dSm^{-1}. Our estimates further showed that at 16 dSm^{-1} of salinity Suaeda nudiflora, Portulaca oleracea, Suaeda fruticosa, Salsola banjosma, Haloxylon recurvum, Atriplex lentiformis and Atriplex amnicola could phytoaccumulate 101.3, 89.4, 74.7, 66.7, 62.1, 60.6 and 56.7 kg ha^{-1} $year^{-1}$ of toxic salt ions in their above ground biomass, respectively. These findings are in concomitant with decrease in soil ECe at the rate of 2.31 to 2.86 dSm^{-1} per year. It is opined that these salt hyperaccumulator plants are fit for further pilot and field level phytoremediation studies.

III. CONCLUDING REMARKS AND FUTURE PROJECTIONS

On the basis of the present investigation, it is inferred conclusively beyond doubt that Chenopods particularly like Suaeda nudiflora, Suaeda fruticosa all the three Atriplex spp., Haloxylon recurvum, Salsola baryosma and to some extent Portulaca oleracea (Portulacaceae) were able to phytoremediate the saline soils very efficiently and effectively. These could provide proficient, sustainable and low cost plant based technology for greening of saline waste lands, amelioration of physical and chemical nature of top layer of soil especially in arid and semi-arid tracts of India. These plants also provide fodder, substituted vegetables, grain, fire (fuel) wood and oil and hence are economically viable plants as well for live stock and rural people. These also stabilize consistently ever eroding saline lands. Feasibility in the near future is the production of bio-salt from these hyper accumulator plants.

In fact these plants use sun's energy to remove salt ions from soil. So transpiration/translocation mediated and active uptake of salt ions is the core of phytoremediation technology. Secondly, the various halophytic taxa especially occurring in saline wastelands could be tailored depending upon the magnitude of salinity or site variations or economical utility of the plants and for additional saline soil reclamation. This bioremediation technology involves the repeated cropping (harvestings] of these hyperaccumulators (as has been done in the present investigations as well) until the soils have reached acceptable levels for the farmers to cultivate their regular crops since root stocks of these plants regenerate vegetative after harvesting of above ground plant parts. Even various saline parks could be raised where co-cultivation of these salt hyper accumulators along with other commercial crops could be undertaken for soil salinity amelioration on an ongoing basis. Even wheat, Brassica, Sesbania and other grasses which have been more economically viable as well can also be grown side by side with these hyperaccumulator plants for complementary use in various crop systems. Furthermore, these hyperaccumulator plants could be harvested and dumped as manageable efficient salt concentrations at point sink, or incinerated for further mineral industrial uses as well. Another most effective utilization of these harvestings from these hyperaccumulator plants could be towards bio-salt production, which shall facilitate natural cycling of the salt.

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Phytoremediation of salt-affected soils: a review of processes, applicability, and the impact of climate change.

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Soil salinization affects 1-10 billion ha worldwide, threatening the agricultural production needed to feed the ever increasing world population. Phytoremediation may be a cost-effective option or the remediation of these soils. This review analyzes the viability of using phytoremediation for salt-affected soils and explores the remedial mechanisms involved. In addition, it specifically addresses the debate over plant indirect (via soil cation exchange enhancement) or direct (via uptake) role in salt remediation. Analysis of experimental data for electrical conductivity (ECe) + sodium adsorption ratio (SAR) reduction and plant salt uptake showed a similar removal efficiency between salt phytoremediation and other treatment options, with the added potential for phytoextraction under non-leaching conditions. A focus is also given on recent studies that indicate potential pathways for increased salt phytoextraction, co-treatment with other contaminants, and phytoremediation applicability for salt flow control. Finally, this work also details the predicted effects of climate change on soil salinization and on treatment options. The synergetic effects of extreme climate events and salinization are a challenging obstacle for future phytoremediation applications, which will require additional and multi-disciplinary research efforts.

Economic feasibility and socio-economic impacts of biosaline agro-forestry system; A case study of salt-affected soils in Haryana, India.

Stille, L.C.

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(Master thesis)

Abstract

The aim of this research was to determine the economic feasibility and socio-economic impacts of biosaline agro-forestry plantations in Haryana India. Five product chains that are derived from the biosaline agro-forestry plantation on salt affected (potentially) waterlogged soils were analysed and compared with the baseline use of similar land before plantation establishment. Every product chain begins with the biomass production phase and has five different output products. These are fuelwood, fuelwood/timber, fuelwood/charcoal, electricity and pulp. The analysis includes all inputs (costs, labour, transportation, energy and processing) to produce an unit of output product (ton or kWh). In this way, the NPV, return on labour (RL), production costs (COP) and labour generated of the biosaline agro-forestry system will be assessed. Also, the potential soil reclamation (phytoremediation function) is assesed and financially valuated by using the substitution cost, land increase value and hedonic price evaluation. The value from these calculations is counted as a benefit in the NPV and RL methods. The five product chains were analysed using 5 different case study sites in Haryana, India. When looking at all the results it is clear that the biosaline agro-forestry plantations can be economically feasible. It depends however on the plantation set-up. The best model for the biosaline agro-forestry plantation is the use of (relative) high value tree species (E. teriticornis and A. Nilotica) in combination with fast growing intercrop species such a L. fusca. This generates the highest economical return. Although the baseline has a higher NPV and RL as the plantations, a comparison is difficult because of the large uncertainties in the baseline values. The (market) value of the finished products from the different tree species also reflects in the economic performance of the product chains, as well as the conversion efficiency (from tree to output product) and percentage of the tree that can be used for timber and fuel wood. If the aim is the production of fuel wood, timber and charcoal it is best to use high value tree species with a high conversion efficiency (A. nilotica and ,to a lesser extend, E. teriticornis). However, if the aim is the production of pulp or electricity, in which the type of tree biomass is not important, it is best to use fast growing tree species such as P. juliflora. Furthermore, electricity production is in all cases (except Gudha) not economically viable. But can be positive because of the added benefits of bringing electricity to isolated rural communities and it's subsequent development of industries based on the availability of electricity. From a socio-economic point of view, the highest labour generation of 17 man-days/ton is achieved by the fuel wood/timber product chain. The soil improvements caused by the biosaline agro-forestry plantations are evident and substantial. The available soil measurements from before and after plantation show a substantial improvement in the soil quality. Also, the local farmers practiced normal agriculture on the plantation lands for as long as 20 years after the tree plantation was removed. Thus normal agriculture is possible and can be sustained for relative long periods of time after the plantation is removed. The economic value of this phytoremediation function can have an significant effect on the economic feasibility of the plantations, but the best method depends strongly on the specific conditions at the location. The important factors are the severity of the soil conditions, the value and scarcity of land and the value and use of the baseline. But when the method is used the NPV (in the case of the village Puthi) can be more than 3 times higher than without the added benefit. show less

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PHYTOMANAGEMENT: PHYTOREMEDIATION AND THE PRODUCTION OF BIOMASS FOR ECONOMIC REVENUE ON CONTAMINATED LAND

Phytoremediation of soil salinity using salt hyperaccumulator plants

SaritaDevi; Rani,C.; Datta,K.S.; Bishnoi,S.K.; Mahala,S.C.; Angrish,R., 2008:Phytoremediation of soil salinity using salt hyperaccumulator plants. Indian Journal Of Plant Physiology: 4, 347-356

Various salt hyperaccumulator plants collected from semi arid saline areas of North-West India - Haryana and Rajasthan like Arundo donax, Atriplex nummularia,Atriplex lentiformis