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Research Article

BIOREMEDIATION OF SALINE SOILS USING AQUATIC PLANTS

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ABSTRACT

Semi arid zones of Rajasthan is facing increasing salinization which has significant and detrimental impacts on land, water and vegetation quality, wildlife environments, agronomy and ecosystem functioning.. Halophytes which represent about 1% of the world's flora, have evolved complex mechanisms at different levels enabling them to successfully cope with these hostile conditions. There are about a billion ha of salt-affected land worldwide, which are unsuitable for agriculture and may therefore provide unique opportunities for "halo-biotechnologies" zones and creation of sustainable production systems. Halophytes growing in wetlands and aquatic regions are able to survive and are able to reproduce in environments where salt concentration reaches or even exceeds seawater salinity level. The successful rehabilitation of saline marginal zones by introduction of halophytes largely depends on collecting reliable data on salt-tolerance limits during life cycle of the respective candidate species. Sambhar lake is the largest inland saline wetland of India It covers an area of 190 sq km in the gaps of Aravalli mountain ranges. The vast saline expanse of the wetland has supported 12 different species belonging to 10 genera and 7 families. Salt production, drainage ground water extraction and grazing have been amply focussed as threats to the lake in last two decades. In recent year man made activities in the catchment area, top soil removal from the lake decades mushrooming of private salt industries , air water and noise pollution including vehicular trespass, poaching, biotic interference including human pressure and unregulated pilgrimage tourism are threats not only to lake ecology but for biota to withstand the adversity. The present paper deals with the halophytic vegetation of Rajasthan with respect to field studies.

Keywords: Salinity, Halophytic, Sambher Lake, Aquatic Plants, Bioremediation.

INTRODUCTION

The aquatic species from roughly one percent of the total angiosperm flora of the world presently. Although Rajasthan is considered desert state but it has rich aquatic flora and biodiversity. Out of an estimated 1500 species of plants in the state nearly one fifth are aquatics[1-3]. Reports published exclusively on the aquatic plants of the state are not many[4-8]. Some of the reports include Ajit Sagar bandh[9]; Bharatpur[10], Ghana bird sanctuary[11]; Alwar[12]; Kota[13]; Bundi district[14] and Jaipur district[15,16]. Pareek[17,18] carried out detailed investigations on several aquatic species from Rajasthan. The aquatic habit has been adopted by diverse groups of angiosperms from fresh water to marine. Although food supply currently is sufficient to feed the world population, more than 850 million people still suffer from chronic malnutrition. Growth of the human population by 50%, from 6.1 billion in mid-2001 to 9.3 billion by 2050 (http://www.unfpa.org/swp/2001/), requires a significant and concomitant increase of crop production to ensure food security, especially in the developing countries. Yield loss due to saline soils is a common problem all over the world as most crop plants are glycophytes and, hence, sensitive to salinity. 97.5% of the world's water is saline, and large land areas are naturally saline. Salinity affects 7% of the world's land area, which amounts to 930 million ha based on FAO 1989 data[19]. The area is increasing; a global study of land use over 45 years found that 6% had become saline[20]. This amounts to 77 million ha. In Australia alone, 2 million ha have become saline since clearing began a century ago, and another 15 million ha are at risk of becoming saline in the next 50 years (National Land and Water Resources Audit; http://audit.ea.gov.au). Irrigation systems are particularly prone to salinization; about half the existing irrigation systems of the world are under the influence of salinization, alkalization or waterlogging[19]. The plants had to adapt accordingly in order to withstand salinity. Some varieties are able to cope with salinity levels as high as those present in sea water (electrical conductivity (EC) 40 dS/m to 400 mM NaCl)[21,22]. Reducing the spread of salinization, and increasing the salt tolerance of high yielding crops, are important global issues.

Halophytes are plants that can complete their life cycle in soils with salinity concentrations above 200 mm NaCl or even above sea water salinity. Halophytes which represent 1% of the world's flora, thrive in a wide range of habitats, from arid regions to coastal marshes. Several species grow in waterlogged or flooded soils, even withstanding total immersion in seawater[23]. Some halophytes require fresh water for germination and early establishment but can tolerate higher salt levels during vegetative and reproductive stages, other's may germinate at high salinities but require lower salinity for maximum growth[21]. In extreme cases (obligate or euhalophytes), increased biomass production occurs only under increased salinity. Further, some plants grow well on permanently wet areas, others grow best where the soil dries out in the summer[24]. Several species grow in waterlogged or flooded soils, even withstanding total immersion in seawater[23]. Some halophytes require fresh water for germination and early establishment but can tolerate higher salt levels during vegetative and reproductive stages, other's may germinate at high salinities but require lower salinity for maximum growth[21]. In extreme cases (obligate or euhalophytes), increased biomass production occurs only under increased salinity. Further, some plants grow well on permanently wet areas; others grow best where the soil dries out in the summer[24].

Aquatic ecosystems are the most productive ecosystem and provide a resource of food and raw materials with a very high economical value to the national and regional economy. They are important for economical activities such as fishery transportation wild life hunting recreation bird watching, surfing, and camping besides providing a natural equilibrium.

MATERIAL AND METHODS

Plant were collected from Sambhar lake , Deedwana, and Pachpadra, identified using Herbarium specimens cited in RUBL and mentioned in my PhD thesis[25].

RESULTS

The area of secondarily salinized lands is increasing at a faster rate over time. Many irrigation districts around the world are shrinking as a result of secondarily salinized soils. This is resulting in crop yield losses. Irrigation practices with low drainage are intensifying this problem. Bioremediation of salinized soils with halophytes is one of the means of reversing this process. In these studies, we tested the growth and performance of four salt tolerant halophytes to varying levels of salinity Salinity reduces the ability of plants to take up water, and this quickly causes reductions in growth rate, along with a suite of metabolic changes identical to those caused by water stress. Halophytes can be used to remediate abandoned salt affected lands and their biomass can have an added economic value. On the other hand, domestication of wild halophytes for agronomic purposes represents another opportunity to address the increasingly salinized soils and shortages of freshwater around the world. In these studies, we assessed the potential for improvement of an oilseed halophyte, through selective breeding.

Aquatic plants of saline conditions:

1. **Aeluropus lagopoides (L.) Trin-ex Thw. (Poaceae):** A tufted rigid perennials stem crowded, resembling stolons, giving off branchlets at the nodes but not the roots. Head of spikelets shortly pedunculate.Fls. & Frts - September.. Rhizomes elongated; scaly; hairy.Butt sheaths villous. Culms geniculately ascending, or prostrate; 5–30 cm long. Leaves cauline; distichous. Leaf-sheaths loose; open for most of their length; 0.4–1 cm long; longer than adjacent culm internode; without keel; indistinctly veined; glabrous on surface, or pilose; outer margin glabrous (hyaline). Leaf-blades lanceolate; 0.5–4 cm long; 2–3 mm wide; coriaceous; stiff; glaucous. surface ribbed; scabrous; rough on both sides; glabrous, or pilose, margins entire; scaberulous. Ligule a ciliolate membrane. Leaf-blade base broadly rounded; symmetrical.
2. **Cyanodon dactylon (L.) Pers. (Poaceae)** also known as *dūrvā* grass, *Dhoob*, Bermuda grass, bermudagrass, *dubo*, dog's tooth grass, Bahama grass, devil's grass, couch grass, Indian *doab*, *arugampul*, *grama*, and scutch grass.Perennial herbs salt-tolerant and easy to manage Culms rooting at basal nodes; branches ascending. The blades are a grey-green colour and are short, usually 2–15 cm long with rough edges. The erect stems can grow 1–30 cm tall. The stems are slightly flattened, often tinged purple in colour. The seed heads are produced in a cluster of two to six spikes together at the top of the stem, each spike 2–5 cm long.. It has a deep root system; in drought situations with penetrable soil, the root system can grow to over 2 m deep, though most of the root mass is less than 60 cm under the surface. Spikelets secund biseriate, lemna herbaceous, boat shaped. Lodicules 2. caryopsis orbicular - oblong. The grass creeps along the ground and roots wherever a node touches the ground, forming a dense mat. It reproduces through seeds, runners, and rhizomes. Fls. & Frts - November – May.
3. **Cyperus lavigatus L. (Cyperaceae):** Erect, perennial herbs, rhizome creeping, covered with brown scales, stems solitary or tufted. Heads with 1-30 spikelets, brown. Glumes ovate or oblong, mucronate. Nuts dorsoventrally compressed. It is native to most continents and grows in wet areas, especially in brakish water wet alkaline soils, mineral-rich springs , and other moist
4. **Cyperus rotundus L. (Cyperaceae):** A perennial herbs, rhizome stoloniferous, leaves few basal, The names "nut grass" and "nut sedge" (shared with the related species *Cyperus esculentus*) are derived from its tubers, that somewhat resemble nuts, although botanically they have nothing to do with nuts. Leaves sprout in ranks of three from the base of the plant. Inflorescence simple or compound, spikelets compressed, brown. The flower stems have a triangular cross-section. The flower is bisexual and has three stamina and a three-stigma carpel. The fruit is a three-angled achene. Fls. & Frts - August – November.

5. **Ludwigia adscendens (L.) Hara (Onagraceae)** Aquatic floating herbs; aerophores spongy. Stem bearing at nodes tufts of aerating roots. Fls. solitary, sparsely pubescent. Stamens 10 (usually double the number of petals) seed pale-brown. Water primrose is an aquatic or sub-aquatic perennial herb that may be emergent, may be anchored, with horizontal extensions over the water surface, or may be free floating. A lovely plant with catchywhite flowers. Leaves 1.5-3.5 x 0.5-1.5 cm, obovate to oblanceolate, base attenuate, apex obtuse, lower surface glossy. Flowers solitary, axillary, to 4 cm across. Calyx tube c. 1 cm long, pubescent; lobes 5, narrow-lanceolate. Petals 5, obovate, emarginate or rounded at apex, cream coloured or white with an yellowish blotch inside. Stamens 10; filaments subequal. Ovary 5-locular; ovules many; style hairy at base; stigma globose. Capsule c. 2.5 cm long, terete, 10-ribbed, dehiscing by 4-5 valves. Fls. & Frts - September - November.
6. **Remustia vivipara (Roxb.) Schott. (Araceae)** A tuberous perennials bulbiferous herbs, Lvs 10-30 cm and a little less broad and look very tropical, being shiny and pleated, with prominent veins.long, ovate - orbicular, base cordate, long petioled. It will also grow as an epiphyte, that is how versatile it is, though it is best not dried out between waterings. Fls. in spadix Fls - not observed.
7. **Salsola baryosoma (Roem. et Schult.) Dandy (Chenopodiaceae):** Erect, much branched, hairy under shrubs ; branches crowded, fls. borne in short, cylindric spikes. Perianth silvery - white winged, wings broad. ovary ovoid or sub-globose. .The plant is very salty. Camels will graze it but it is taken only reluctantly by other stock. It is commonly used as camel fodder. Fls. & Frts. September – March
8. **Suaeda fruticosa (L.) Forsk. (Chenopodiaceae):** Erect much branched glabrous, shrubs. fls. solitary or more usually 5-7 (-12) in an axil. Perianth sub globose. Seeds black, shining, smooth. High salt tolerance of this species has been reported by Khan et al., (2000), and therefore, the association of this species with highly salt tolerant species can be easily expected. Fls. & Frts - September – March
9. ***Suaeda maritima* (L.) Dumort. (Chenopodiaceae);** Stem woody at the base, erect 3.7 - 5 cm high. Fls. in small subglobose clusters arranged in spikes. Seeds obliquely ovoid or sub-orbicular, smooth, shining black.
10. **Tamarix aphylla (L.) Karst. (Tamaricaceae)** A shrub, often a small tree, branches having deep punctate glands. Fls. bisexual, borne in lax racemes or panicles. Capsule trigonous, rounded at tip. Fls.&Frts - July - October.
11. **Trianthema portulacustrum L. (Aizoaceae)** Radially spreading upto 50 cm long, pubescent perennials herbs. capsules thin walled at base. Fls. & Frts - August - November, Rarely March to April.

Soil bioremediation by desalination-efficient halophytes: In the arid to semi-arid regions, water quality is a major factor limiting crop . Growth activity of the annuals is governed by the rainfall regime, the rainy season extending from autumn to spring, while the perennials grow slowly, but are able to cope with water shortage and soil/water salinity. Variations in biomass and productivity among and within natural ecosystems may be attributed mostly to differences in water and nutrient (especially N) availability and salinity[26]. Understanding the functioning of plant saline ecosystems capable of significant productivity under salt stress is of paramount importance in perspective of improvement of soil characteristics using halophytes.

The annuals were almost exclusively clustered under the halophyte tufts, or at their immediate vicinity, where soil nitrogen and inorganic phosphate levels were significantly higher, and salinity significantly lower than between the halophyte tufts. Furthermore, the shoots of the annuals growing in association with halophyte species contained relatively low Na^+ concentrations. These findings indicate that the upper horizon, enclosing the halophyte tufts (where sensitive annuals grew), is fertile and contains low salt levels. This was also corroborated by the study of soil samples taken from the upper profile in the tuft center. Desalination of the upper horizon by the superficial roots of halophytes could be responsible for this micro-gradient of salinity. Further, the litter formed by halophyte fallen organs and by organic debris accumulated by the wind at the vicinity of halophyte tufts, could contribute to localized soil enrichment in N and P. Hence, the upper soil profile, where these plants grew, was fertile and contained (relatively) low salt levels, as corroborated by the results of soil analyzes (upper horizon in the tuft centre was always less saline than when taken at the tuft periphery). Soil aeration near the annual glycophytes would be improved by this organic matter and by the higher soil level under the tufts, leading to better drainage capacity. Halophytes may also play an indirect role by developing deep root systems exploiting the more saline horizons, as shown by the presence of halophyte roots at 1 m depth and by the vertical increasing salinity gradient. So, the halophytes directly contributed to maintenance of a relatively low salinity and high fertility in upper horizon, enabling the growth of annuals.

Bekki[20] showed that *Medicao ciliaris* plants growing in combination with *Suaeda fruticosa*, had a higher growth rates and better nodulation and nitrogen fixation potentialities than isolated ones. Several studies have highlighted the advantageous role of halophytes in soil desalination processes, especially for the most productive species, such as *Salsola spp.*

DISCUSSION

Relatively high salt tolerant species like *Aeluropus lagopoides* and *Suaeda fruticosa*, showed a broad range of association at all study sites irrespective of salinity level of the habitat. In contrast, in moderately salt tolerant species.

Saline habitats, especially in the deserts are characterized by specific plant communities[27]. Distributional patterns of the flora in salt affected habitats often reveal strong associations of specific taxa with certain types of soil solutes. Solute composition, along with salinity and habitat stability, may provide a template shaping the distribution of many plants inhabiting saline habitats. Studies on habitat associations, specific solute tolerance, and ionic and osmotic adaptations of a particular species provide evidence about the fidelity to particular conditions[28]. Since saline desert conditions are rare in nature, this kind of typical habitat is very unique. Plants inhabiting such conditions are very different and, therefore, phytoecological studies of saline habitats in desert conditions are useful for understanding of adaptive mechanisms.

CONCLUSION

Further investigations are needed to evaluate the influence of the combined effect of temperature and salinity on quinoa germination and also on later plant growth stages. This knowledge may allow the assessment of a variety's capability to perform under a certain combination of these two environmental factors and may therefore be of particular value when considering the cultivation of quinoa in salt affected regions in high temperature climates.

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