CHAPTER 3

GAINFUL UTILIZATION OF SALT AFFECTED LANDS: PROSPECTS AND PRECAUTIONS

RAZIUDDIN ANSARI, M. AJMAL KHAN AND BILQUEES GUL

Institute for Sustainable Halophytes Utilization,
Department of Botany, University of Karachi,
Karachi-75270, Pakistan

Abstract: Soil salinity which is rampant and unevenly distributed in arid and semi-arid areas of the world, retards plant growth through osmotic and specific ion effects. In order to gainfully utilize these soils, we need either to improve the soil or enhance salt tolerance limit of existing plants through genetic manipulation. Both are theoretically possible but the former i.e. soil improvement is more feasible and has a history of success while the later requires sophisticated instrumentation and better comprehension of the underlying processes involved in achieving the desired objectives. Taking into consideration the inherent ability of certain plants to tolerate salinity, there is yet another easier and more practical approach of screening and selection of suitable species/varieties from the already available germplasm and use them for cultivating saline lands as such. The paper discusses the possibility of using woody species in saline lands, proposes some methods for better growth under such conditions and warns of probable consequences in following this approach.

1. INTRODUCTION

Salinity, generally synonymous with sodium, is the presence of excess salts in the root zone in concentrations that retard plant growth. This reduction in growth depends primarily on the inherent salt tolerance of the plant which is exacerbated by environmental factors like vapor pressure deficit, radiation, temperature and a host of other interacting influences both within and outside the plant.

The estimates of salt affected lands vary widely i.e. between 340 and 950 x 10^6 ha because the data are imprecise and different agencies have used different criteria of classification (Flowers et al., 1986). According to conservative estimates however, about 7 % of total land area of the world is saline to varying degrees and is unevenly spread over the continents, generally in arid and semi-arid regions (Szabolcs, 1987; UNEP, 1992). Inter-regional variation exists both among the countries and in the regions with in a country. In Pakistan for instance, where substantial salinization is reported in all the provinces (Table 1, Anonymous,

M. Kafi & M.A. Khan (eds.), Crop and Forage Production using Saline Waters. Vol: X, 103-108

2004), the southern part is comparatively more saline both quantitatively as well as qualitatively.

Table 1: *Extent of salinity (area in million ha) in Pakistan*

Province	*Total area*	*Cultivated*	*Salt affected*
Punjab	20.63	12.27	2.67
Sindhs	14.09	5.65	2.11
Balochistan	34.72	2.11	1.35
NWFP	10.17	1.84	0.05
Total	79.61	21.87	6.18

Note: About 40000 ha become saline each year due to secondary salinization
Annual loss to the economy is in the region of approx US$ 3 billion

The salinity may be due to saline parent material or it may have developed by the intervention of mankind. Irrigated agriculture is often practiced without taking into consideration of the requirement of the crop or applying enough quantities to meet the leaching requirement. Over or under-irrigation both create problem, the former leads to water logging and later leaves salts in the root zone. Under arid climates where saline soils are abundant, high evaporation from the soil surface continuously brings up more water from root zone and below through capillary rise and results in salt accumulation on the surface. Keeping in view the total quantity of water applied during a given season, it happens even when good quality irrigation water (this contains 600-1000 ppm salts) is used, highlighting the necessity to adopt proper management practices to avoid or minimize this development.

2. OPTIONS AVAILABLE TO COMBAT THE HAZARD

Under such conditions, according to the old adage, either improve the soil or change the existing crop and use a tolerant species/variety suited to the prevailing conditions. A third option, yet to materialize fully, suggests bringing changes in the genetic makeup of a sensitive plant to make it grow under harsher conditions. Considerable progress has been and is being made on all the three fronts. Lowering underground water table, using suitable agronomic practices and adding ameliorants to soil help in improving the situation. On the other hand, plant breeders and physiologists have realized the importance of joining forces to identify the causative factors and genes involved in conferring tolerance or sensitivity in order to attempt gene manipulation.

The main hindrance in transferring desirable character(s) from a salt tolerant species to improve the less tolerant one lies in the fact that unlike biotic stresses, insect or disease for instance; salinity tolerance is a multigenic character (Chaubey and Senadhira, 1994) and there are, as yet, few readily recognizable genes to try and select (Winicov, 1994). It may also be worth mentioning here that tinkering with a number of genes at a time may create a situation where back crossing fails to dilute the alien undesirable genes effect and while attempting to introduce one desirable character; it also opens the possibility of knocking out other good characters or consecutively introducing undesirable traits in the progeny (Flowers and Yeo, 1995). Although this is a viable option but requires a cautious approach.

3. THE WAY FORWARD

The above leads us to the comparatively easier and more practical option of identifying species/cultivars from the available germplasm which are tolerant of salinity and can be directly planted in the affected areas. A large number of studies have been conducted in the past and new papers continue to appear on the subject but the need continues to expand this activity further depending on particular requirements. We discuss here the results from a project conducted in collaboration with the Australian CSIRO, which aimed at exploring the potential of some woody species from Australia and Pakistan for utilization of saline areas. The experiments were conducted simultaneously in Pakistan and Australia but the paper draws heavily from the work in Pakistan. The experiments were conducted at NIA experimental farm located at 25^{o}, 24'north, 31' east in southern Sindh, Pakistan. The soil was medium in texture, showing high heterogeneity in salinity ranging from 7.3 to 26.5 dSm^{-1} in 0-60 cm soil layer recorded with EM-38, and with a shallow ground water table.

Based on growth performance, observations recorded after three years of growth, the species under test sowed diverse response to salinity levels and accordingly separated into three categories (Table 2). *Acacia species*, both from Pakistan (there was only one- *Acacia nilotica*) and others from Australia proved to be performing very well in their respective category. *Acacia nilotica*, although it was not very salt tolerant, but survived occasional water logging and once established, performed very well subsequently. Because of its socio-economic importance (almost all parts from root to fruit are used in one way or another, Ansari et al., 1998) it may be an important component of the system in moderately saline conditions prone to occasional, but not sustained, inundation. *Prosopis juliflora* and *Tamarix* species, also from Pakistan, performed very well and survived salinity above 16 $mScm^{-1}$.

The acacias from Western Australia were generally tolerant of salinity but *Acacia ampliceps* was the best, followed by other species i.e. *machonochieana, A. stenophylla* and *salicinia*. Provenance variation within species also existed. Australian acacias however, performed poorly under salinity plus prolonged water logging condition. None of the Eucalyptus survived above 10 $mScm^{-1}$.

The following cultural practices were recommended for improving growth of woody species planted in saline/sodic fields.

1. Excess water should be removed from soil surface as well as from the root zone, either through vertical drainage (tube well) and/or horizontally (ditches/trenches, tile drain). In case of presence of hard pan near root zone, mechanical ripping or digging of auger holes in the field may be helpful.

2. In areas affected by water logging, planting on mounds is advised to give seedlings elevated position above the water. The combination of these two stresses is any way hazardous in most cases.
3. Application of mulches to reduce evaporation and accumulation of salts at or near the soil surface helps in moisture conservation and sustained growth.
4. Addition of organic and inorganic fertilizers e.g. farm yard manure, NPK, Zinc is helpful. Inoculation with suitable rhizobia/frankia often improves growth of N-fixers. Gypsum may be needed against the threat of sodicity.

Table 2: *Classification of some woody species based on their salt tolerance*

Salinity (Electrical conductivity of soil saturation extract in dSm^{-1})		
4-8	**8-16**	**>16**
*Acacia auriculiformis**	*Acacia salicinia*	*Acacia ampliceps*
*Acacia nilotica**	*Casuarina glauca**	*Acacia machonochieana**
Acacia saligna	*Casuarina obesa*	*Acacia stenophylla**
Acacia tortilis	*Conocarpus lancifolius*	*Melaleuca halmaturorum*
Albizzia lebbeck	*Eucalyptus camaldulensis**	*Prosopis juliflora**
Azadirachta indica	*Eucalyptus occidentalis*	*Tamarix aphylla**
*Casuarina cunninghamiana**	*Eucalyptus rudis*	*Tamarix articulata**
Casuarina equisetifolia	*Eucalyptus tereticornis*	*Tamarix gallica**
*Eucalyptus citriodora**	*Melaleuca leucodendra**	
*Eucalyptus grandis**	*Zizyphus jujube*	
Eucalyptus robusta		
Leucaena leucocephala		
Melaleuca arcane		
*Melaleuca bracteata**		
*Parkinsonia aculeate**		

Notes:
1. Provenance variation within species is often very important for response
2. Species marked with an [*] may tolerate occasional water logging
3. 1 dSm^{-1} = 1 $mScm^{-1}$ = 10 mM or 0.06 % NaCl approximately

Using heat pulse technique, studies on water consumption by three year old trees of *Acacia nilotica* and subsequent effect on under ground water table showed a gradual water draw down under the plantation during summer, the water started rising with cooler temperature and returned to initial level at the end of winter (Figure 1, Khanzada et al., 1998). The area surrounding the experimental field remained fallow during summer but was planted with irrigated wheat in winter. The wheat planting starts in middle October, which coincides with the onset of rising water table under the plantation. It however, demonstrates the potential use of trees to act as biological pump and lower the under ground water table.

4. PRECAUTIONS AND PITFALLS

The seed of Australian species was brought from areas which were carefully matched with the environmental conditions of the experimental sites in Pakistan.

However, introducing alien material to a new habitat requires great precautions in view of the ecological consequences, which could be drastic. The Australian species of this project have, to the best of our knowledge, not spread widely in Pakistan, probably because of lack of proper back up and extension. However, an earlier introduction, also from Australia-*Eucalyptus camaldulensis*, needs mention here. It was one of the test species of the present study as well but was overshadowed by other species, particularly acacias.

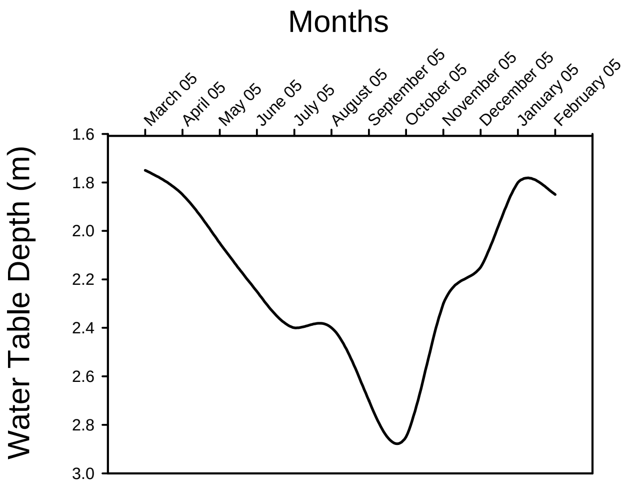

Figure 1: *Fluctuation in underground water table of a three year old plantation of Acacia nilotica trees*

The forest departments of Pakistan spent lots of their resources to popularize *Eucalyptus camaldulensis*, which undoubtedly has fast growth rate and the potential of tolerating moderately saline conditions. It was distributed extensively and people planted it indiscriminately in saline and sweet soils alike, without realizing that it was a heavy consumer of water. Another problem, although debatable, related to allelopathic effects. The leaves contain volatile chemicals, the stem and branches have limited utility as fuel wood and there is a saying that even the birds do not nest on this tree. It may be a habitat for koalas, but there are no koalas outside Australia. *Eucalyptus* growers in Pakistan realized primarily ill effects on the adjoining crops, caused most probably by water depletion, and found it hard to sell their trees when they reached marketable stage.

This does not imply that *Eucalyptus* is entirely useless. It is a source of chemicals and the wood pulp is used in paper manufacturing. The relevant industries in Pakistan should have been geared up in advance to accept the responsibility of proper utilization of the raw material in time to start processing it when the crop became ready to harvest. Without this arrangement the *Eucalyptus* growers were left with a dilemma of what to do with these trees.

The same may hold true to some extent for the Australian acacias, mainly due to their limited utility. They may be acceptable as fuel wood and are definitely good colonizers of high saline areas. Another useful attribute is being non-thorny, which makes them easier to handle and graze, although no systematic animal feeding trials appear to have been conducted. These trees generally have multi-stems from the base (generally undesirable) and the wood is not as good as that from *Acacia nilotica*. The large within-provenance variation offers opportunity of screening and selection for desirable characters.

Lowering underground water table by trees, also observed in the present study, is possible but should be viewed with caution as also reported by Heuperman, 1992; Thorburn, 1996 and more recently by Barrett-Lennard, 2002. The evapo-transpiration increases the hydraulic gradient towards the root zone of the plantation and continuous water consumption by the vegetation results in gradual buildup of salts left behind in the root zone. Ultimately, a stage is reached when the ability of roots to function properly is impaired encouraging rise in water table. This may be a long term scenario (10-20 years) but one that one should be ready to expect and combat with.

5. ACKNOWLEDGEMENTS

The seeds of Australian species were supplied by the Australian Tree Seed Centre, Canberra, Australia, while the Australian Centre for International Agricultural Research (ACIAR) provided partial financial support.

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