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SALINE AGRICULTURE: PROMISES AND PROSPECTS FOR FUTURE AGRICULTURE IN DEGRADED SALINE LANDS

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Abstract

One third of the world's 2.3×10^8 hectares of irrigated land is salt-affected and, with the general demand for freshwater increasing, maintaining the supply for agriculture becomes more difficult. The utilisation of halophytic plants (crops adapted to saline conditions) for producing food, forage, fibre, and edible oil is one possibility. There are around 2200 known species of halophytes, 350-400 in Pakistan. They range from grasses and shrubs to trees and inhabit west seacoast marshes and dry inland saline deserts. Two-thirds of the country receives under 350mm of annual rainfall, while the barren Balochistan coastline is virtually dry, rendering conventional agriculture impossible. Seawater irrigation using local halophytes has the potential to create a profitable oilseed industry here.

The twin menace of waterlogging and salinity has been combated for decades in Pakistan by expensive *engineering methods* using drainage systems to lower water tables, *reclamation approaches* such as salt leaching and adding chemicals to improve soil conditions, *saline agriculture in situ* for useful biomass productivity and *genetic techniques* to confer salt tolerance.

Saline water, finally, can be transported to the deserts. Following rainfall, grasses are produced with numerous tillers, allowing many cattle to be sustained throughout the year. Thus even the deserts can function as a productive ecosystem.

Introduction

Salinity is the predominant problem of the world's cultivated land particularly so in the semiarid and arid regions About 23% of the world's 1.5 x lO^9 ha of cultivated land is saline, and 37% is sodic (Pessarakali and Szabzolcs, 1998). One-third of the world's 2.3×10^8 ha irrigated land is salt-affected. In addition, population growth rate is highest in tropical and subtropical regions. These regions have 93 million hectares available for the fields to expand.

Over the next three decades it is estimated that over 200 million hectares are required to feed the growing human population. Owing to rapid urbanisation the demand for freshwater is increasing and so it is becoming difficult to maintain the existing level of freshwater supply for agriculture. Clearly we need alternative sources of water and land to grow crops, as illustrated below.

The induction of salt tolerance is the approach which has commonly been, employed by workers during the past half century with limited success. The upper salinity limit for the long term irrigation of even the most salt tolerant

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crops is still less than 5 ppt (parts per trillion). Yet the concentration of salt in low quality water is above 10 to 20 ppt and for seawater salinity ranges from 35 ppt (Atlantic Ocean) to 45 ppt (Arabian Sea and Persian Gulf regions). Changing the basic physiology of traditional crop plants would be difficult and it might be more appropriate to domesticate wild salt tolerant plants as food, feed, fibre, forage or oil-seed crops. Certainly our modern crops started out as wild plants.

The utilisation of the halophytes (plants adapted to saline conditions) is an old approach. During the ancient civilisation of Mesopotamia, farmers used deep-rooted perennial halophytes (e.g. *Alhaji maurorum)* to reclaim the farmland which had became saline due to freshwater irrigation. During the recent past brackish water and direct seawater have been used to grow some plants and it has been convincingly demonstrated that seawater irrigation is a distinct possibility. Saline agriculture must fulfil two requirements to be cost-effective. Firstly, it must produce useful crops at high enough yields to justify the expense. Secondly, the agronomic techniques should be developed for seawater agriculture with minimum damage to the environment.

There are about 2200 species of halophytes, from grasses and shrubs to trees such as mangroves. They occupy a wide range of habitats, from wet seacoast marshes to dry inland saline deserts (Menzel and Lieth, 1999). There are several groups around the world working on this topic. Most noted among them are those of Glenn and O'Leary from the University of Arizona, Tucson, (Glenn *et al*., 1998), Pasternak at the University of Negev, Israel (Pasternak and Nerd, 1995). And a European Community Concerted action group co-ordinated by Lieth from Osnabruck University, Germany (Lieth, 1999) which uses Mediterranean and subtropical deserts to conduct his experiments. These groups use seawater irrigation. They irrigate the plants daily by flooding the coastal fields with highly saline (40 ppt) seawater. Although the yield has varied among species, the highest production was about one to two kgm^{-2} of dry biomass. Some of the most productive and salttolerant halophytes were shrubby species of *Salicornia*, *Suaeda*, and *Atriplex* from the family Chenopodiaceae. Salt-tolerant grass such as *Distichlis spicata* and viny, succulent-leaved ground coverers such as *Batis* were also highly productive. Helmut Lieth also grew halophytes successfully both in coastal and inland desert conditions of the UAE. He used brackish water irrigation in inland areas and direct seawater irrigation in the coastal areas successfully. Some other groups from Morocco, Tunisia, Israel, Italy, Egypt, Saudi Arabia, Pakistan and India have also used seawater irrigation to grow various halophytic crops both under field station and greenhouse conditions.

Prospects and pitfalls

On the positive side, about 2200 halophytic species are available in the world (Menzel and Lieth, 1999), with more to be discovered. A significant number of these plants show optimal growth under seawater irrigation, while others could survive but would produce lower biomass yields. Yet some others could grow well under brackish water irrigation. These plants could survive in coastal areas, inland saline deserts, waterlogged conditions, wetlands, etc. Specialised irrigation equipment is available which could prevent salt damage to the system. Daily irrigation with seawater using an effective leaching system prevents salts from building up in the root zone to inhibit growth, while such methodologies have already been verified by growing the plants under natural conditions.

Cultivating plants in salty water will lead to minor local problems that will require specific attention. There would be some degree of degradation in water and land quality sometimes due to brackish or seawater irrigation. This system requires 30% more irrigation in comparison to freshwater to flush out the excess salts from the roots. Pumping of seawater requires special equipment that can resist corrosion due to salt but it makes the whole project expensive. Machine harvesting would be difficult because most of these plants lodge close to the harvest. In some seed crop halophytes the seeds may therefore shatter early.

The case of Pakistan

Most of the regions of Pakistan (67%) receive less than 350 mm of annual rainfall. Agricultural practices have to rely on canal irrigation in most regions. Cultivable areas dominated by canals total around14 million hectares (Mha) out of a total of 30 Mha (Ahmed and Nasri, 1982). However, only 10 MH are used for agriculture since the rest could not be cultivated due to salinity and waterlogging. Canal irrigation results in a high water table and sometimes waterlogging in the command areas. Due to rapid evaporation of water, the salinity level builds up in the soil and could reach up to 8 - 10% of the soil water. About 17 Mha in Pakistan have underground water and 14% contain freshwater. Two million hectares contain water with moderate salinity (100-300 ppt), while the rest (9 Mha) has its salinity higher than 300 ppt. About 5 Mha has a water table less than 1-5m. This area could be classified as the disaster area because it is waterlogged with high salinity and could not be utilised for conventional agriculture. The coastal area of Balochistan is probably one of the most arid coasts of the world, receiving hardly any rain. This barren area has no real agricultural economy.

Definition of the problem

The current population growth rate of Pakistan is high at about 2.75 %per year. The most important resource of irrigation water is the Indus River system. About 54% of this water is lost due to seepage and evaporation. Supplies of freshwater are dwindling because of the increasing pressure of the urban population and high demand of agriculture for freshwater. All this would result in a substantial decline in food production in the face of rapidly increasing population growth. Food production has to be increased to avoid any major disaster. There is an urgent need to devise methods to use low quality water and degraded land to increase the agricultural productivity.

Work done

This twin menace of waterlogging and salinity has been troubling Pakistani planners and politicians for a long time. There have been four major approaches to deal with salinity and sodicity in Pakistan (Qureshi and Barrett-Lennard, 1998).

1. Engineering approach: This approach assumes that salinity in irrigated areas can be reversed using drainage schemes that lower water tables. Over 7.8 million hectares have now been treated using salinity control and reclamation projects. However, the projects are extremely expensive, many salt-affected soils are not treatable, and the sustainability of the approach is questionable.
2. Reclamation approach: The basis of this approach is the use of small-scale interventions to improve soil conditions. This is particularly appropriate where soils are saline because of high sodicity (lack of soluble calcium) and low rate of water infiltration. Interventions include leaching of salt with higher levels of irrigation, the use of chemical amendments (such as gypsum and acids), the use of organic wastes, and the use of plants to improve soil condition. This approach has limited utility.
3. Saline agricultural approach: Under the saline agricultural approach, useful production can be achieved from salt-affected wasteland. In these instances, the main focus is on the utilisation of the land while still in the saline and sodic conditions.
4. No intervention: There are few situations in which doing nothing is the best response, and
5. Breeding for salt tolerance: To confer salt-tolerance to the conventional crop plants was partially successful. Using various genetic and breeding methods, some of the crop plants became relatively more tolerant to the salt. However, the most salt-tolerant conventional crop could not tolerate more than 5 ppt of NaCI and the salinity of our saline lands and brackish water is much higher than this. There are some efforts being made to transport the saline water to the desert. The desert is a productive ecosystem. After rainfall it produces grasses with large numbers of tillers and could sustain a considerable number of cattle throughout the year. Dumping of the saline water to desert would substantially degrade the otherwise productive area. Transportation of saline water through the Indus River during high floods would also increase the salinity in the agricultural areas downstream.

Inland saline agriculture

Few studies have been conducted to determine the productivity of halophytes in Pakistan One of the most prominent was financed by ACIAR (Australian Center for International Agriculture Research), which conducted trials of various *Atriplex* species at four different centres in Pakistan (Karachi, Faisalabad, Peshawar and Bhawalpur) (Ahmed and Ismail, 1991). They reported that *Atriplex* species was very successful in Pakistan (Table 1) and the best performance was given by *Atriplex lentiformis.*

Malik *et al* (1986) reported that Kallar grass *(Leptochloa fusca)* grown on salty soils irrigated with brackish underground water could produce 500t/hay of biomass though this seems an exaggeration. Cultivation of Kallar grass drastically altered the chemical composition of saline/sodic soils, which was reflected in improvement of pH, EC, SAR and ESP compared with the control plots. Khan *et al*., (1986) raised *Prosopis juliflora* in the coastal areas of Balochistan by irrigating it with brackish water (21 dS m^{-1}). More than 300 ha of plantation were successfully developed.

What is to be done?

We propose the cultivation of local halophytes using seawater irrigation in dry barren coastal areas of Balochistan and highly inland saline areas. The introduction of an alien species to an ecosystem is always risky. There are numerous examples which show that it could be dangerous to local biodiversity. Pakistan fortunately has a large number of local halophytes. A rough estimate shows the number of species ranging between 350 to 400 including coastal, inland, and cold desert species. The information concerning salinity tolerance and economic utility of local species is however limited. It is therefore, essential to collect this information to make suitable recommendations for saline agriculture. Suitability of the species would vary with the ecological habitat and utility required.

The data presented in Tables 2 and 3 suggest that some of the local halophytic species are highly tolerant to salt both at the germination and growth stages. Two species *viz Cressa cretica* and *Arthrocnemum macrostachyum* could germinate at 1 M NaCI, a concentration well above seawater (Table 2). Most of the other halophytes showed some germination at seawater concentration. All these species appeared to be more tolerant at the growth stage (Table 3) in comparison to their tolerance at seed germination. All species except for *Atriplex griffithii* and *Halopyrum mucronatum* showed optimal growth at the concentration little higher than seawater. This indicates that most of them could not only grow under seawater irrigation but could also produce considerable biomass This suggests that our local species are more salt-tolerant than any other introduced species and if we could determine the salt tolerance of all species, then we would be able to find a wide variety of halophytes for saline agriculture.

Table 1. Performance of forage shrubs at various ecological haloxeric regions of Pakistan (Ahmed and Ismail, 1991).

Plant Species	Germination				Fresh biomass			
	KAR	FBD	PSH	BWL	KAR	FBD	PSH	BWL
Atriplex amnicola	+	+	+	+	-	4	2	2
A.bunbryana	-	+	+	+	-	3	2	2
A.cinerea	+	-	-	-	-	-	-	3
A. lentiformis	-	+	+	+	-	4	2	3
A. nummularia	-	-	-	-	-	-	-	-
A.paludosa	-	-	-	-	-	-	-	-
A. undulata	+	+	+	-	-	4	2	-
A. vesicaria	+	+	+	+	-	3	2	2
A.halimus	+	+	+	+	-	4	2	2
A. stocksii	+	-	-	+	-	-	2	-

Fresh Biomass (kg) 2 = 0..1-1, 3 = 1-10, 4 = 10-100

Table 2. Salinity tolerance of local halophytes at germination (percentage) stage. (Khan and Gulf, 1998; Khan and Ungar, 1996; 1997 a,b,c; 1998; Khan and Rizvi l994, Noor and Khan,1995).

	NaCl (mM)					
Species	**0**	**200**	**400**	**600**	**800**	**1000**
Arthrocnemum macrostachyum	87	75	67	26	10	2
Atriplex griffithii	70	35	16	0	0	0
Cressa cretica	89	78	65	50	31	16
Halopyrum mucronatum	95	89	15	1	0	0
Haloxyon recurvum	85	43	18	2	0	0
Suaeda fruticosa	99	65	35	6	0	0
Zygophyllum simplex	80	22	2	0	0	0

Table 3. Salinity tolerance of local halophytes at growth (mg plant $^{-1}$) stage (Khan, Ungar, and Showaller, 1999, 2000a,b,c, Khan and Aziz, l998).

	NaCl (mM)					
Species	**0**	**200**	**400**	**600**	**800**	**1000**
Arthrocnemum macrostachyum	87	92	110	126	89	80
Atriplex stocksi	70	35	16	0	0	0
Cressa cretica	51	79	82	93	69	53
Halopyrum mucronatum	62	60	3	0	0	0
Haloxyon recurvum	150	200	275	300	195	140
Suaeda fruticosa	48	76	79	60	39	28

Future suggestions and prospects.

Based on the above-mentioned information it seems obvious that saline agriculture is here to stay and we have to modify our systems according to our resources and needs. The technology of using direct seawater or brackish water irrigation systems has been established in many parts of the world. However, this technology has to be based on local requirements. We have to follow a two-pronged approach. First is to utilise a long barren coast of Balochistan for cultivating plants that could either produce oil seeds, forage, or food. There are more than a hundred species of halophytes reported from the coastal areas of Pakistan. A rapid screening of their salt tolerance should be made. This would help us to select those species which could be grown using direct seawater irrigation. Following this we have to determine how best they could be economically utilised. Analysis of their seeds for oil and their leaves for forage should also be conducted as well as feeding trials to different animals. All this requires that a greenhouse and a coastal experimental site should be established to develop the saline agricultural situation and to transfer the technology over to local entrepreneurs. Similar efforts are needed to develop inland experimental sites. We have a large number of halophytic species and we should determine their level of salt- tolerance and their suitability for inland saline habitats followed by their optimum usage economically according to local needs.

Pakistan is importing most of its edible oil. We believe that if a concerted effort is made there is no doubt that we would be able to produce good quality oil seeds in the barren areas of Balochistan using seawater irrigation. In addition we would also be able to reclaim a vast tract of inland saline areas previously destroyed by salinity using deep-rooted halophytes, and we would also be able to utilise these lands and the low quality of water for the production of food, feed, fibre and seed oil crops. It will require great effort and ingenuity – but it can be done.

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