Prospects of Saline Agriculture in the Arabian Peninsula

Proceedings of the International Symposium on "Prospects of Saline Agriculture in the GCC Countries"

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Amherst Scientific Publishers
150 Fearing Street
Amherst, Massachusetts 01002
USA

Printed in the United States of America

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History of Research on Salt-Affected Lands of Iran. Present Status and Future Prospects

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INTRODUCTION

Iran is the second largest country in the Middle East, with an area of 1.65 × 106 km^2, and lies between latitude 260° and 380° North and longitude 440° and 630° East. Because of this wide range in latitude and longitude, Iran has a diverse physiography, climate, vegetation and biological productivity. While the whole of the Caspian coastal plain is below sea level, the Damavand Mountain (5766 m) is the highest peak between the Alps and Himalayas. Although Iran's climate is characterized by aridity, with more than 30% of the country receiving less than 100 mm of precipitation annually, much of the Gilan province in the Caspian area receives from 1000 to 2000 mm annually (Table 1). Nearly 72% of the area is located in zones with less than 300 mm rainfall, 17% in areas with 300–500 mm, less than 8% in areas with 500–1000 mm and 1 % in areas with more than 500 mm (FAO, 1997). Salinity is a major concern of agriculture in Iran. The magnitude of the area of the salt affected soils can be explained by their wide distribution, covering more than 30% of the total surface area of the irrigated land (Table 2) (World Resources, 1987). Besides the naturally occurring salt-affected soils, the extent of man-made salinized soil is also significant. This is mainly a consequence of improper irrigation management. As the demand for food from plants increases, the decreasing availability of fresh water for agricultural use is a common problem in many parts of Iran. This requires an increasing use of lower quality or saline water for crop production. Fortunately, there are abundant sources of such water that could be used for irrigating crops. However, the salinity of those water sources typically exceeds the limit tolerated by conventional crop plants. The availability of saline water, marginal lands and salt-tolerant plants, which are the fundamental parts of biosaline agriculture,

TABLE 1. Distribution of precipitation in Iran

Annual Precipitation (mm)	(km²)	(%)
<50	100 000	6
50–100	285 000	17
100–200	465 000	28
200–300	370 000	23
300–500	280 000	17
500–1000	130 000	8
>1000	18 000	1
Total	1648 000	100

Source: Massoumi (1984)

TABLE 2. Estimates of percentage of irrigated land affected by salinization for some Asian Countries

Country	% Affected
China	15
India	27
Iran	<30
Iraq	50
Palestine	13
Jordan	16
Pakistan	<40
Sri Lanka	13
Syria	30–35

Source: World Resources (1987)

requires a better understanding of the relationships between these components when under proper management.

GENERAL CHARACTERIZATION

Cultivated area

Table 3 shows that wheat, rice, cotton, sugar beet, potato, onion and tomato, are, respectively, the main cultivated crops for the growing years 1991–1998.

Distribution of the saline area

Saline and sodic soils are predominant in Khozeestan (17% of the area) and Central province (16.5% of the area). Ghilan, Kordestan and Bakhtaran provinces have the smallest areas of such soil types (Table 4).

TABLE 3. Cultivated area of main crops in Iran (1000 ha)

	Main Crops						
	Wheat	Rice	Cotton	Sugar beet	Potato	Onion	Tomato
1991	6193	573	205	173	141	44	66
1992	6640	597	171	205	155	46	89
1993	6807	588	141	180	151	39	104
1994	6782	563	185	204	150	40	92
1995	6567	566	272	203	145	48	104
1996	6328	600	320	149	143	41	119
1997	6299	563	238	191	158	46	95
1998	6180	615	229	185	163	48	120

Source: Agricultural Statistics and Information Department (2000)

Research Organizations and Institutions Involved in Salt Affected Lands

1. Universities: There are 22 colleges of agriculture in different Universities which are involved in various research projects in salinity, mainly as theses for post graduate students.
2. The Ministry of Agriculture Agricultural Research, Education and Extension Organization (AREEO) is the main body for agricultural research on the different aspects of crop production including salinity studies. The Soil and Water Research Institute of this organization has been involved in different soil and water projects on salin-

TABLE 4. Distribution of saline and sodic soils (x1000) in different provinces of Iran

Province	Total Area (ha)	Saline Soils Area (ha)	Saline Soils (%)	Saline Marshes Area (ha)	Saline Marshes (%)	Total Area (ha)	Total (%)
Ghilan	3800	—	—	—	—	—	—
Mazandaran	14000	400	2.86	1600	11.40	2000	14.26
Tzarbayejan	10500	360	3.48	120	1.14	480	4.62
Kordestan	3132	—	—	—	—	—	—
Bakhtaran	6212	—	—	—	—	—	—
Khozestan	13466	1000	7.54	1260	9.47	2260	17.01
Farse	17420	1640	9.40	120	0.67	1760	10.07
Kerman	23280	1740	7.56	400	1.72	2140	9.28
Khorasan	30900	800	2.59	1600	5.18	2400	7.77
Isfahan	17600	760	4.32	920	5.23	168	9.55
Balochestan	18500	520	2.81	1240	6.70	176	8.51
Central Province	6200	80	1.29	920	14.86	1000	16.51
Total		7320	4.45	8180	4.97	15500	9.42

Source: Soil and Water Research Institute (1987)

ity. Recently a salinity research institute has been established in Yazd.

3. The former Ministry of Jihad Sazandegi, which recently merged with the Ministry of Agriculture to become the Ministry of Jihad-e-Keshavarzi (Agriculture), has been involved in salinity aspects related to natural resources and particularly to rangeland.

RESEARCH PROJECTS CONDUCTED DURING THE PAST 35 YEARS

In total 432 projects have been conducted on different aspects of salinity of which 53% were concerned with soil, 20% with water and 27% with the other aspects of salinity (Figure 1). Of the total research projects con-

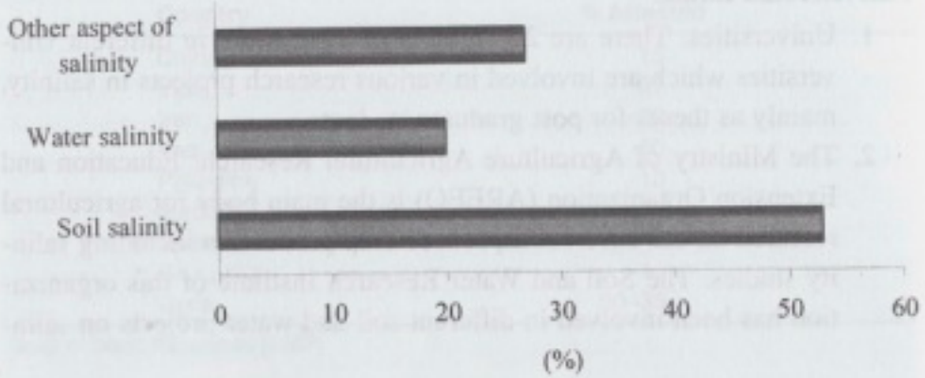

FIGURE 1. Percentage of total projects related to soil and water

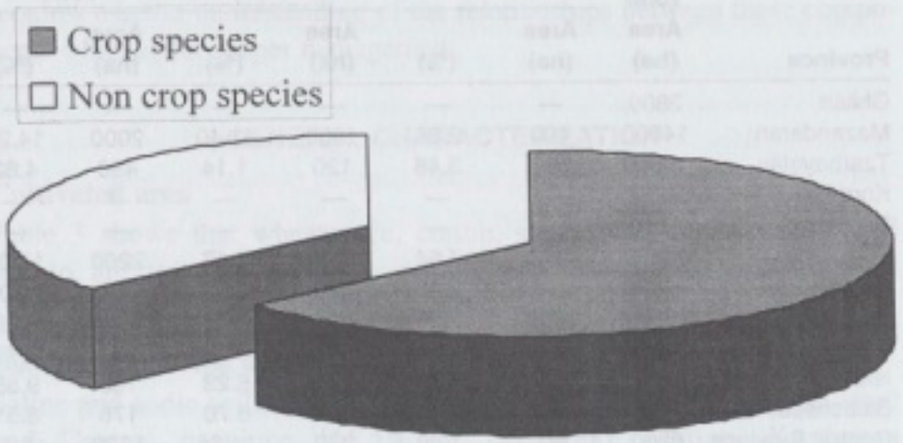

FIGURE 2. The contribution of crop species from total plant salinity research projects in Iran

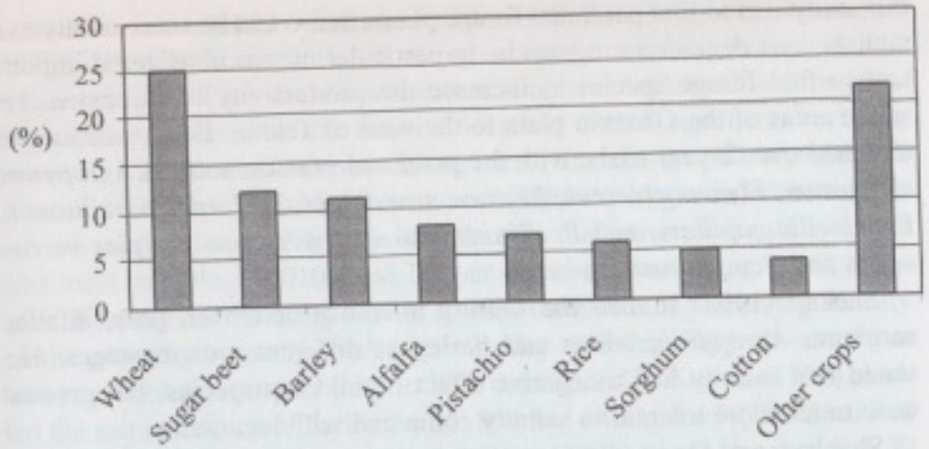

FIGURE 3. Percentage of total research projects on the basis of commodities

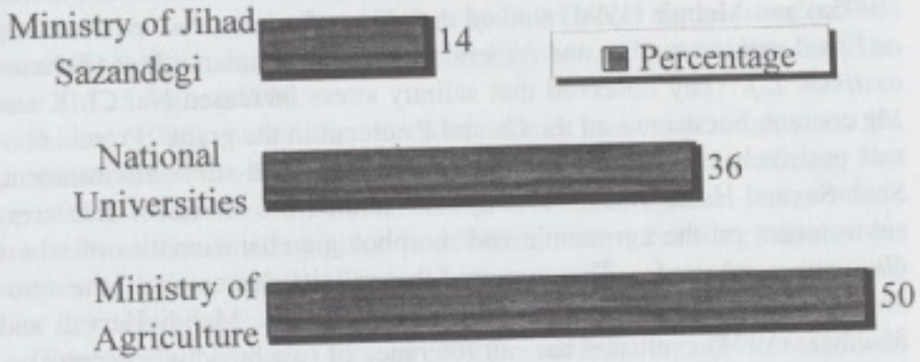

FIGURE 4. The contributions of the Ministry of Agriculture, National Universities and the Ministry of Jihad Sazandegi in salinity research projects in Iran

ducted on salinity 64% were related to field crops (Figure 2). On the basis of commodities, these projects were concerned with wheat, sugar beet, barley, alfalfa and pistachio (Figure 3). Of these projects, 36% were conducted by the universities, 50% by the Ministry of Agriculture and 14% by the Ministry of Jihad Sazandegi (Figure 4).

REVIEW OF MAIN SCIENTIFIC WORK CONDUCTED ON SALINITY IN IRAN

Crop resources

Nernick (1986) studied the role of the Food and Agriculture Organization of the United Nations in promoting the establishment of forage plants in a number of countries including Iran, Iraq, Pakistan, etc. The objective of

this study was to find perennial forage plants that could be successfully established on degraded rangelands. In particular, it was considered important to find forage species to increase the productivity of the extensive saline areas of the Ghazvin plain to the west of Tehran. Best results were obtained over 2-year trials, with the perennial grasses, such as *Agropyron elongatum*, *Elymus cinereus*, *Festuca arundinaceae*, *Hordeum bulbosum*, *Puccinellia capillaris* and *P. distans*, and shrubs such as *Atriplex verrucifera* and *Camphorosma perenne*.

Shekari (1993) studied the salinity tolerance of clover, peas, alfalfa, sorghum, *Agropyron*, wheat and barley at different growth stages. He stated that salinity had a negative effect on all crop species, but grasses were much more tolerant to salinity compared with legumes.

Shahbazi and Doust (1996) studied the accumulation of organic and inorganic matter in salt-stressed wheat cultivars. They concluded that there was no positive correlation between proline and soluble sugar accumulation and wheat relative to tolerance to salinity. Shah Savand Hasni *et al.*, (1995a) and Malmir (1994) studied the effect of a salt-stress environment on bread making quality and mineral elements in Iranian wheat (*Triticum aestivum L.*). They observed that salinity stress increased Na, Cl, K and Mg content, but decreased the Ca and P content in the grains. Protein content positively correlated with Na and P under a salt-stress environment. Shah-Savand-Hasni *et al.*, (1995b) also studied the effects of salt-stress environment on the agronomic and morphologic characteristics of wheat (*Triticum aestivum L.*). They reported that salinity decreased all the agronomic traits except the number of grains/spikelets. Majidi Hervan and Shahbazi (1994) evaluated the salt tolerance of two bread wheat cultivars under different salt solutions and observed that the cultivar Shoeleh was more tolerant than Bayate. Poustini and Baker (1994) reported a parallel reduction in CO_2 uptake, transpiration and stomatal conductance in two wheat cultivars indicating that, under saline conditions, stomatal resistance to CO_2 may greatly cause reductions in photosynthesis. Poustini and Salmasi (1997) studied the effect of salinity on dry matter production and remobilization in two wheat cultivars in the greenhouse. They showed that both cultivars experienced significant reductions in total dry matter production and significant increase in dry matter remobilization under saline conditions.

Taghvaii *et al.*, (1998) studied salt tolerance of the calluses of six wheat cultivars obtained from tissue culture on different media. They stated that the highest regeneration rate was achieved from 2,4-D-free media, and increased NaCl concentrations in the medium caused reduction of callus growth. Safar-Najad (2001) studied the responses of the callus of three varieties of wheat at different concentration of manvitol and NaCl in media. He reported that the amount of protein and some of the antioxidants increased in salt tolerant varieties. Poustini and Yusefi-Rad (1999) studied the effects of salinity stress on nitrogen uptake and distribution in two wheat cultivars. They demonstrated that N uptake decreased with increasing salinity levels, but the rate of decrease varied significantly, being lower in the tolerant cultivar Tabassi than in Inia-66. Mirodjaghi and Arzani (1999) assessed 28 durum wheat (*Triticum turgidum*) cultivars for *in vitro* salt tolerance. They reported that the relative growth rate of callus was most reliable. PI40100 and Dipper 6 had the best *in vitro* salt tolerance. Kassray and Doering (1989) studied the effect of increasing salinity on the germination and growth of two barley varieties. They observed that both varieties performed better in KCl than in NaCl. Karimi (1996) studied the salt resistance of barley for Cl, 804 and HCO_3. Taeb (1998) studied a total of 44 accessions, including 14 from 3 *Hordeum* species and 30 genotypes from 5 *Aegilops* species for sodium and potassium ion accumulation as well as morphological characters combined with 19 years of climatological data. He stated that there was considerable variability among species in Na^+ accumulation. *Aegilops speltoides* had the least sodium accumulation (10.5 mgl mgDW) whereas *Hordeum spontaneum* had the most (16.25 mg/mg DW).

Farasat (1994) studied the effects of salinity and temperature stress on germination and the early growth stages of different varieties of rice. She reported that different salinity levels significantly decreased the germination and coleoptile elongation. In addition, with increasing salinity the number of leaves, length of roots, height of plants, root dry matter and total dry matter were decreased.

Fouman and Majadi-Hervan (1992) studied the salt tolerance in sorghum. Samdani (1994) studied the mechanism of resistance to salinity in 18 sweet sorghum varieties (*Sorghum bicolor* Moench). He reported that salinity decreased the germination of sorghum varieties. In addition, resistance to salinity at germination had no relationship with resistance at the seedling growth stage.

Dori (1994) illustrated an approach to evaluate the salt tolerance of *Medicago sativa* seedlings during germination, emergence and establishment. He concluded that using salt boxes was the best approach in selecting tolerant alfalfa seedlings. Rahmani (1989) studied the salinity tolerance of some alfalfa varieties at different growth stages. He reported that with increasing salinity, germination speed, number of germinated seeds, length of premula and length of radicle decreased. Valizadeh (1997) studied salt and alcohol-soluble proteins in leaves, seeds and chloroplasts of 9 *Medicago* species using SDS PAGE.

Nazem-Bokaie and Fahimi (1999) studied the interaction of salinity and phytohormones on the germination of *Vicia faba* seeds. They stated that apparently auxin does not play a role in germination improvement

under salinity conditions while having an undeniable role in increasing plant height under normal conditions. Nasiry-Mahallati and Sarmadnia (1990) studied the effect of sodium chloride on the growth indices of bean plants (*Phaseolus vulgaris L.*) under different climatic conditions. They concluded that in a dry and saline environment there was a linear and significant correlation between leaf water potential and leaf chloride content. Islam-Zadeh (1991) studied the effects of plant growth regulators on *Phaseolus vulgaris*. She reported that auxin and gibberalic acid did not increase the salinity tolerance in *Phaseolus vulgaris*. Nadjafi and Mirmasumi (1999) studied the physiological responses of soybeans (*Glycine max L. Merr.*) to salt stress. They reported that with increasing salinity the concentrations of proline and alanine were increased and the concentrations of glycine and glutamic acid were reduced.

Ranji *et al.*, (1997) studied the proline accumulation in sugar beet plants under different salinity levels. They stated that the synthesis of proline increased at the beginning of using saline levels and later gradually decreased.

Sarmad (1992) studied the effect of different salinity concentrations on growth analyses and the photosynthetic efficiency of sunflower. He reported that with increasing NaCl concentrations, the value of NAR, RGR and RLGR declined and the concentration of chlorophyll a and chlorophyll 'b', increased.

Maibody (1999) studied the effect of the kinetin on the development of immature detached spikes of *Cynodon dactylon* under salt stress and normal conditions. He stated that adding NaCl to the medium harmed embryo development and resulted in the production of abnormal seeds. The abnormal seeds were smaller in diameter with a more fragile peri carp.

Yazdani (1992) studied the tolerance to salinity of tomato and onion varieties in Iran.

Hashemi-Dezfouli and Alemi-Saeid (1997) studied the germination and initial growth of the epicotyl of Jojoba (*Simmondsia chinensis*) at different temperatures and salinity levels. They concluded that although Jojoba might potentially withstand high salinity levels, this is only true after the establishment of a well-developed root system. Mohsenzadeh (1999) studied the effect of plantation bed and auxin concentration on the rooting of Jojoba stem cuttings. He reported that differences due to number and length of roots under the effect of the plantation bed were significant. A mixture including peat was better for plant establishment, but hormone concentrations showed no marked differences.

Koocheki and Zarif Ketabi (1996) studied four regimes temperature and four levels of salt stress on seed germination, coleoptile length and number of radicles for six range species. They reported that seed germination and number of radicles were reduced more with salt stress compared to water stress.

Soil and water resources

Keshavarz and Brown (1998) studied the drainage problems in the Amir Kabir Sugarcane Irrigation Project, located in Ahwaz, Iran. They found that natural drainage is inadequate to control the groundwater table due to rain and excess irrigation. They remarked that a high water table and the loam-silt soil texture are the main reasons for the lack of natural drainage. However, because of highly saline soils and groundwater, it is necessary to control the salt balance, prevent soil salinity after initial leaching, and remove excess water by deep percolation and subsurface drainage. Sohrabi and Gazori (1997) studied subsurface irrigation with porous pipes. They reported that on salt movement, the salt gradient increased from the water source toward the surface. Gorji Anari and Rafahi (1995) studied saline water of the "Ajichai" watershed and the effect of erosion on its quantity in Eastern Azarbaejan, Tabriz. They reported that surface erosion had little effect on the salinity of the river. They added that the main reason for the salinity of the river was attributable to infiltrated water, which is the main source of the dissolution of salts, which finally joins to main river. Shiati *et al.*, (1998) reviewed the use of brackish water as a source for irrigation in Iran. Abtahi (1977) studied the effect of saline and alkaline groundwater on soil genesis in semiarid southern Iran. Abtahi *et al.*, (1979) studied soil-forming process under the influence of saline and alkaline groundwater in the Sarvestan Basin. Shiati (1991) demonstrated a regional approach to salinity management in river basins.

Karimi (1997) studied the desalinization of heavy textured soils in the Tabriz floodplain by ploughing at various depths. He reported that with shallow (25–30 cm) ploughing, leaching was not very efficient. However, with deeper (45–50 cm) ploughing, more than 50% of the salts were removed, whereas subsoiling (75–80 cm) reduced salinity to a level suitable for plant growth. Farahbakhsh and Towfighi (1997) studied the relationship between electrical conductivity, concentration of total soluble salt content and chloride ion concentration in salt affected soils of Iran. They stated that the chloride ion was the dominant (>50%) anion in two-thirds of the soil samples, indicating the widespread presence of chloride salts.

Pazira *et al.*, (1998) evaluated four mathematical models with different physical and theoretical backgrounds against measured soil salt concentration within two test sites at two major reclamation projects in Iran. Khodagholi *et al.*, (1999) studied the vegetation and soil in geomorphological units of south Daryach-e Namak (salt lake). They reported that there was a close relationship between vegetation and geomorphological units in the Cenozoic, but no specific relationship can be seen in the Qua-

ternary era. Hoveizeh (1997) studied the saline habitats of the north Hoor-e-Shadgan in South Khuzestan province. Akhavan-Ghalibaf *et al.*, (1994) studied the soil resalinization in the Rudasht region of Isfahan. They concluded that the factors contributing to salt accumulation and redistribution in the region were heavy soil texture, relief, earth canals, and the system of water application and distribution. Akhavan Ghalibaf *et al.*, (1996) studied the hardpan and salt distribution in the Rudasht of Isfahan, Iran. Neekmaram and Rezaie (1992) studied the effect of a different amount of elemental sulfur on the reclamation of saline sodic soils. Panah *et al.*, (1999) studied the soil salinity in the Ardakan area of Iran based upon field observations and remote sensing. Akhavan-Ghalibaf (1991) studied the causes of salinity in some soils and the effect of salinity on pedogenesis in the Rudasht region of Isfahan, Iran. Rajabi (1992) studied the effects of different amounts of compost in the soil on salinity and soil pollution, and also the absorption of heavy metal by maize. He stated that two percent compost in the soil has no salinity effect, but with increasing the compost, the soluble potassium increased. Abtahi *et al.*, (1980) studied the mineralogy of a soil sequence formed under the influence of saline and alkaline conditions in the Sarvestan basin. Mahjoory (1979) studied the nature and genesis of some salt affected soils in Iran.

Nemati (1977) evaluated the problems of rehabilitation of the steppic zone in Iran by summarizing some ecological factors affecting vegetation growth and recommending suitable techniques. He mentioned that due to low precipitation, extreme temperature and commonly saline and alkaline soils, natural revegetation was extremely slow and reseeding of different species had not shown success. Mohajer-Milani and Javaheri (1998) studied the water requirements for the reclamation of salt affected soils in different parts of Iran and for different crops. Mohamdi (1991) compared two different leaching methods for reclamation of saline-sodic soils in Rudsht, Isfahan, Iran. Mosavi-Khansari (1991) studied the different physico-chemical reclamation of saline and sodic soils in plain of Saveh in the central province of Iran.

FUTURE RESEARCH PRIORITIES

Although salt tolerant crops have been used in small-scale farming systems by farmers in many countries, adaptation of new technologies, based on site specific approaches and niche planting, is needed. There is still tremendous potential for the utilization of these genetic pools associated with emerging needs, such as environmental remediation (e.g. carbon sequestering), greening the stressed species, use as a cash crop, etc. Therefore, priorities should be given to:

- New approaches for better utilization of saline soil and water.
- Scaling up the present indigenous knowledge available for the utilization of saline soil and water.
- New looks at the present plant resources in salt affected lands for the purposes of better preservation and conservation of genetic pools.
- Molecular and ecosystem evaluation of conventional and new salt tolerant crops.
- New ways for rendering these plants fit for human consumption.
- Establishment of a national strategic plan for research in salt affected lands based on integrated approaches.
- Better understanding of the environmental aspects of salt affected ecosystems.

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