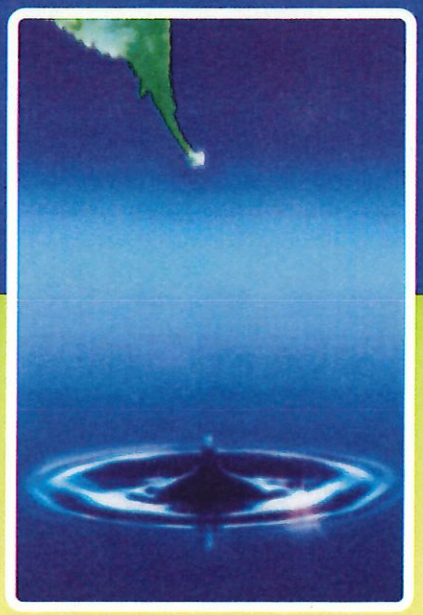
Prospects of Saline Agriculture in the Arabian Peninsula



EDITORS

Faisal K. Taha

Shoaib Ismail

Abdullah Jaradat

Prospects of Saline Agriculture in the Arabian Peninsula

Amherst Scientific Publishers  Amherst, Massachusetts USA

Prospects of Saline Agriculture in the Arabian Peninsula

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

EDITED BY
Faisal K. Taha, Shoaib Ismail
and Abdullah Jaradat



International Center for Biosaline Agriculture (ICBA)
Islamic Development Bank (IDB)
International Center for Agricultural Research
in the Dry Areas (ICARDA)
Ministry of Agriculture and Fisheries (MAF), United Arab Emirates

Amherst Scientific Publishers
150 Fearing Street
Amherst, Massachusetts 01002
USA

Printed in the United States of America

ISBN: 1-884940-32-3

Contents

Contributions of Kuwait Institute for Scientific Research to Biosaline Research and Development

Samira A. S. Omar and Nader Al-Awadi

Kuwait Institute for Scientific Research

INTRODUCTION

Kuwait is located in the northwest of the Arabian Gulf, where the environment is harsh and arid, soils are highly saline soils and temperatures are extreme during summer. The limited natural water resources are mostly saline (3000–8000 ppm TDS) making conditions very severe for agricultural development which is, therefore, very low, representing less than 0.4% of GNP (Omar *et al.*, 1987). Most food is imported from other countries to meet the ever-increasing demand for food for human and animal consumption.

The genetic diversity of native halophytic plant species in Kuwait has not been fully investigated for its productive potential. Some progress has been made in selecting a few species that have potential as greenery plants and/or for rehabilitating degraded lands. In recent years, biosaline research and development has become important and is vital for technical developments that will lead to feasible plant production under the harsh climatic conditions of Kuwait.

The Kuwait Institute for Scientific Research (KISR) has long been involved in biosaline research and development, which started in the 1980s with screening of germplasm of wheat, salicornia, rangeland shrubs and ornamental plants for salt tolerance, and led to joint sponsorship of a biosaline conference in 1992 (Al-Nasser, 1992). More recently, intensive programs on plant selection for salt tolerance and on tissue culture, and genetic engineering manipulation related to it, have been with implemented. KISR has devoted much attention to the analysis of salinity tolerance. Omar (1985), and Omar *et al.* (2000), identified endemic plants of Kuwait, which have the inherent genetic capacity to withstand stresses such as salinity, heat and drought. Several species of *Atriplex* (*A. nummularia, A. canescens, A. lentiformis, A. glauca, A. nuttalli,* and *A. rhagoides*) were in-

troduced to the rangelands by KISR. All *Atriplex* species showed excellent growth potential. However, prostrate-growing species like *A. glauca* and *A. nuttalli* became covered with wind-blown sand drifts (Taha and Omar, 1988). AboEl-Nil (1994a) found that mangrove cultivars tolerate Kuwaiti saline conditions and grow productively. Additionally, over the past years, mangrove production with seawater was demonstrated in the Kuwait coastal zone. Studies by Sharma *et. al.* (1990), and Sharma and Ibrahim (1989), using somaclonal variations, as well as traditional breeding techniques, selected salt-tolerant cultivars of eggplant and cucumber. None of these cultivars, however, exhibited true halophytic characteristics and it remains to be seen whether or not the salt-tolerant characteristic is stable and will be inherited in the progenies. Research in other organizations in Kuwait, particularly the Public Authority for Agriculture and Fish Resources (PAAF) on selecting salt-tolerant tomato cultivars, also received attention. A number of vegetables, including tomato, pumpkin, watermelon, melon and okra, were screened in the field using brackish water (7000 ppm TDS). However, crop production was significantly less than when these vegetables were cultivated with fresh water (Saleem and Al-Shayji, 1997). More recently, KISR moved aggressively towards achieving more significant results by adopting and improving advanced technology for biosaline research. In the post-liberation period, several projects were initiated, which focus on selecting genotypes and germplasm of highly salt-tolerant fodders and crops. KISR further developed its capabilities for conducting more sophisticated research, such as molecular biology and tissue culture techniques, in addition to traditional cultivation techniques.

KISR's research and development achievements in the field of biosaline agriculture are presented here, highlighting the main issues of concern, the future research strategy and collaboration with regional and international institutions.

SALINE SOURCES AND AGRICULTURE

Salinity problems in Kuwait are being detected in irrigated farming (Al-Rashed and Al-Ghawas, 1999; Abdal *et. al.*, 1999, Omar *et al.*, 1998) and coastal areas (Al-Sarawi *et al.*, 1985; KISR, 1999), where water-borne salts are accumulating in the soil during repeated cycles of water reuse and sea-water intrusion, respectively. The saline soils in Kuwait are generally quoted as occupying an area of about 209,000 ha (Hamdallah, 1997). No detailed survey has been conducted on the existing agricultural areas in Kuwait. Aquisalids soils make up 27.27% of area (473,627 ha) in Kuwait (KISR 1999).

The main sources of water for agricultural use in Kuwait are ground-

water, treated wastewater and desalinated water. Groundwater is mostly saline, with only limited fresh or brackish water (Al-Sulaimi *et al.*, 1996). The estimated available groundwater in Kuwait is 247 million imperial gallons per day (MIGD) and Total Dissolved Salts (TDS) range between 3000–8000 ppm. At present, over 60% of field irrigation and all landscape irrigation in Kuwait is from groundwater.

A CENTER OF EXCELLENCE IN R&D

KISR's overall objectives and research unit structure

In 1981, an Amiri Decree granted KISR its own charter, with objectives focusing on advancement of industry; protection of the environment; utilization of water resources, natural resources, and energy resources; improvement of agricultural activities; diversification of national revenues; and service and advice to private and pubic institutions. Likewise, this Decree charged KISR with the establishment of cooperative relations with leading centers of scientific research in Kuwait and abroad.

Organizationally, KISR now has five research programs:

1. Petroleum Resources
   a. Oil Production
   b. Petroleum Refining
   c. Petrochemical Processes
2. Food Resources and Greenery
   a. Aridland Agriculture and Greenery
   b. Biotechnology Applications
   c. Aquaculture, Fisheries and Marine Environment
3. Environment and Urbanization
   a. Environmental Management
   b. Coastal Management and Atmospheric Pollution
   c. Urban Infrastructure Development
   d. Advanced Systems
4. Water Resources
   a. Water Technologies
   b. Water Resources Management
5. Techno-Economics
   a. Economic Studies
   b. Quantitative Analysis and Modeling

The Food Resources and Greenery Program houses research and development in the field of salt-tolerance. Strong matrix support is provided to FRD by the Water Resources Division, particularly through its Water Technologies and Water Resources Management Departments, and by the

Environment and Urbanization Division, via its Coastal Management and Atmospheric Pollution program element.

KISR General Technical Support Capabilities

Several units in KISR provide services and technical support to research programs. These units are described as follows:

1. Central Analytical Laboratory (CAL)

CAL provides reliable, accurate and prompt analytical services, including the establishment or development of needed methodologies. CAL analyzes a wide range of materials, including almost all tissues and materials related to food and agriculture. CAL's sophisticated analytical facilities include: nuclear magnetic resonanace (NMR); infrared coupled with gas chromatograph (GC-IR); scanning electron microprobe analyzer, gas chromatograph/mass spectrometer, inductively-coupled plasma optical emission and mass spectrometer; X-Ray diffraction and fluorescence spectrometer; amino acid analyzer, gas chromatographs; high performance liquid chromatographs; auto analyzer; CHNOS analyzer; UV/VIS/NIR spectrometer and other instruments.

2. National Scientific and Technical Information (NSTIC)

NSTIC's main objectives include providing scientific and technical information services to R&D programs and projects, government authorities, and scientific, commercial and industrial institutions. It serves to strengthen ties with other Arab scientific centers and institutions, particularly in the GCC. NSTIC's specialized collection includes over 55,000 book titles, a large collection of reference materials, 800 periodical titles and over 350,000 research reports on microfiche, as well as a large collection of world patents and microfilm and 20,000 titles of different standards. NSTIC has become a sophisticated information center, serving as a model in the Gulf and Arab region.

3. Information system Division (ISD)

The Information Systems Division (ISD) provides computing facilities and services: to support strategic and operational decision-making; to support research projects; and to administer data as a corporate resource. KISR's ISD has cutting-edge information technology consulting capabilities, including statistical analysis, database establishment, and administration of e-mail, internet and network stations.

Research Capabilities of the FRD

In addition to KISR's main building, many field facilities and laboratories are being established for agricultural research including biosaline research. These are described as follows:

Sulaibiya Agricultural Experimental Station
A 2000-hectare fenced Agriculture Experimental Station with groundwater of about 3500–4000 ppm TDS. This station is equipped with modern irrigation systems for field crop experimentation, a desert plant development sub-station, a range research grazing establishment, a greenhouse, and sheep and poultry housing facilities, along with feed storage units.

Waterfront Experimental Site
Two 5.2-hectare experimental sites on Kuwait's prominent waterfront. These experimental sites have direct access to brackish groundwater as their water source. Both sites are used for testing and demonstrating plant salt tolerance under coastal and wind-borne salt conditions.

Mudaira Seawater Plant Testing Station
The Mudaira Sea-Water Plant Testing Station is a 5-hectare fenced site, with its own water wells, and is situated directly on the northern coast. These wells draw water that ranges between 35,000–40,000 ppm TDS. However, the site was severely damaged during the Gulf War. The site was used for testing *Salicornia* plant growth under Kuwait environments.

Inter-tidal Mud Flat Mangrove Development Sites
KISR has a number of inter-tidal mudflat mangrove sites on campus and on the northern coast. These sites are used for establishing pilot plantations and undertaking mangrove improvement studies.

Tissue Culture Center
A 1500m^2, well-equipped, modern tissue culture center for experimental studies, training and mass production of salt-tolerant plant materials.

Plant Genetic Engineering Laboratory
A genetic engineering laboratory wherein plant salt tolerant genes can be isolated, identified and manipulated.

Environment Controlled Greenhouse
A large 1000 m^2 environmentally controlled greenhouse for acclimatization and grow-out of salt-tolerant and genetically manipulated plants. The proximity of this facility to the tissue culture and genetic engineering laboratories makes it especially relevant to biosaline research work.

Agronomy Laboratory
An agronomy laboratory, equipped for seed testing, seedling trials, physiological adaptation and screening of germplasm.

Soil and Water Laboratory
A soil and water laboratory and a close association with the Soil Survey Laboratory and GIS capability. The water laboratory is fully equipped for complete analysis of water samples.

Biochemistry and Analytical Laboratory
A biochemistry laboratory for the study of plant tissues and animal feeds, supported by full analytical capabilities.

RESEARCH AND DEVELOPMENT IN BIOSALINE

For more than 30 years, KISR contributed to biosaline research in collaboration with PAAF. Together they have recognized that the agriculture sector in Kuwait can be expanded only through selecting and naturalizing plants that can tolerate increasing salinity levels in soil solutions. In this context, the Food Resources and Greenery Program has focused its research program on the following:

- Screening several strains of cultivars for salt-tolerance;
- Developing a Halophyte Testing Station and experimenting extensively with Salicornia (sheep fodder);
- Collecting desert plant germplasm for salt-tolerant studies;
- Developing a Mangrove Testing Center in northern Gulf Waters;
- Adapting PCR technology to ensure trueness-of-type in tissue cultured date palms;
- Perfecting embryogenic tissue culture techniques for mass production of date palms and other plants; and
- Initiating a genetic manipulation of salt-tolerance, using the mangrove salt-tolerant genes as a starting base.

Several projects have been conducted in the above-mentioned areas of research. The general objectives and achievements of the completed and on-going projects are presented in the following section.

Screening several strains of cultivars for salt-tolerance

Vegetables are important components of Kuwait's agricultural production. Soil salinity and irrigation water are limiting factors for expansion of field and greenhouse production of vegetables in Kuwait, and in many other countries in arid regions. This research (AboEl-Nil and Sabah, 1993; Sharma and Ibrahim, 1989) was aimed at selecting salt-tolerant genes, or germplasm, from three important vegetables—tomatoes, cucumbers and eggplants—through the application of conventional breeding and tissue culture techniques. One prerequisite for improving the salt-tolerance of a crop is the presence of suitable genetic variability, which makes possible screening for potentially useful germplasm. *In vitro* studies of eggplants, tomatoes and cucumbers led to the development of five techniques: for

large-scale screening and selection of seeds *in vitro*, regeneration of eggplant from callus cells via embryogenesis, regeneration of tomato plants via organogenesis, regeneration of cucumber plants via embryogenesis and screening for tissue culture using brackish-water stress. Techniques for embryogenesis in cucumbers and eggplants, and for organogenesis in tomato, were developed and are suitable for induction and screening for salt-tolerant somaclonal variations. Studies implementing a conventional breeding approach, using the simple technique of the saltbox, led to the selection of four salt-tolerant eggplant variants. The application of cell and tissue culturing was successful in obtaining culture lines of tomatoes that are also salt-tolerant. Attempts to do the same for cucumbers were not successful. Genetic engineering is the next logical step in producing salt-tolerant cucumbers. Techniques developed in this research should be implemented utilizing the germplasm selected for the production of new and improved cultivars suitable for the saline environment of Kuwait.

Germplasm of plant species, which have good potential for commercial production in the region (such as cabbage, onion, garlic, okra, barley, Rhodos, *Panicum* sp., *Andropogon* sp. and others), have been introduced from various sources and are being screened for salt-tolerance at two stages *viz.* seedling stage, and adult growing stage. The appropriateness of the screening techniques for the test crops under local conditions will be determined by grow-out tests of salt-tolerant lines selected using screening techniques. The information generated and the promising genotypes selected in the research will provide valuable crops for Kuwait and the region (Abdal *et al.*, 2000a,b).

Developing a Halophyte Testing Station and experimenting extensively with Salicornia (sheep fodder)

The main aim of this research was to determine whether the production of improved *Salicornia* species is feasible under Kuwait conditions, using seawater as the only source of irrigation, and to provide a production demonstration for potential clients and/or farmers. The investigation also established whether this crop could be used as fodder and feed for livestock and, thus, reduce Kuwait's dependence on imported feed and fodder for sustaining and expanding Kuwait's livestock industry (El-Bagouri *et al.*, 1988). The *Salicornia* ecotype SOS-7 produced biomass of about 15 tones per ha, which was comparable to the best productivity achieved in Mexico (Abdal *et al.*, 1990). The research site, however, was damaged after the Iraqi invasion.

Collecting desert plant germplasm for salt-tolerant studies

Tissue culture multiplication technology was developed for the four native plant species under investigation in this research (AboEl-Nil, 1997),

namely *Rhanterium epappsoum*, *Lycium shawii*, *Nitraria retusa* and *Ochradenus baccatus*. The basic propagation protocol was *via* axillary bud break and organogenic bud formation on a medium containing an auxin and a cytokinin. Bud elongation followed when cultures were transferred onto a growth-regulator free medium. Rooting was achieved on the same medium supplemented with indolebutyric acid. The techniques developed were streamlined to produce several thousand plants of the last three species, on three different media, thus making commercial large-scale production feasible. Plants grew well in the experimental site and flowered. *Rhanterium* tissue cultured plants were found to be difficult to establish in the greenhouse, while growth in the laboratory, on nutrient medium and in soil, was excellent. The rate of multiplication of all species indicated that it was possible to implement the technology for cost-effective, large-scale propagation. It is envisioned that a pilot-scale production project for the three most promising species can be carried out to produce several thousand plants of each species for desert rehabilitation and greenery activities. As for *Rhanterium epapposum*, further research is required for the acclimatization and soil transfer, and physical and chemical treatments, to simulate a synchronization of the phonological stage of development *in vitro* and *ex vitro*.

Developing a Mangrove Testing Center in northern Gulf Waters

Mangrove (*Avicennia marina*) communities constitute an important component of the vegetatal renewable natural resources of the coastal zones of the Arabian Gulf south of Kuwait (AboEl-Nil, 1994a,b). Mangroves are the most prominent salt-tolerant forest trees of the intertidal regions. They grow in saline, anoxic soils, and under conditions characterized by a combination of high temperatures and irradiance. Mangrove ecosystems of the intertidal zones provide habitats for many organisms, ranging from bacteria and fungi to fish, shrimp, birds and mammals. Mangrove trees produce large quantities of leaf detritus that serve as bases for near-shore food webs. The yield of shrimp fisheries around the world has been closely correlated with the abundance of coastal mangroves. In areas where shoreline erosion is a problem, mangroves provide a reasonable protection from storm waves and play a secondary role in the accumulation of sediment. Natural strains of mangrove have a moderating influence on the local climate and enhance the aesthetic and recreational value of the coastlines. Intertidal mudflats, which cover about 57% of Kuwait's 290-km coastline, are suitable for the introduction of mangroves. The aim of this research (Bhat *et al.*, 2000) is to introduce mangroves into the coastal areas of Kuwait, for the purpose of protection, beautification and enrichment of the intertidal mudflats. Phase I of this project is in progress (Bhat *et al.*, 2000). To expedite the implementation of the introduction of mangroves to

Kuwait, Phase II has been designed to establish silvicultural practices for large-scale production of plants in a nursery, practices for out-planting and to develop techniques for domestication of mangroves (through tree improvement by selecting genetic biotypes that are suitable for successful establishment of mangrove communities in the intertidal mudflats of Kuwait). The project will also evaluate the environmental impacts of the introduction of mangroves on the ecosystems of the intertidal mudflats and the possible effects on fish and shrimp nursery grounds.

Adapting PCR technology to ensure trueness-of-type in tissue cultured date palms

The main aim of this research is to develop and adopt molecular probes, such as restriction fragment length polymorphism (RFLP), for use in ensuring trueness to type. An economically successful date culture program is dependent upon producing and marketing elite, true-to-type date varieties. The costs to date growers and nurseries can be enormous if errors are made in establishing trueness-to-type during tissue culture operations. Thus, the development of a trueness-to-type technology is a pre-requisite for obtaining full economic benefits from any commercial date production operation. The main objective of this project (Saleem *et. al.*, 2000) was to develop a rapid, sensitive, cost-effective technology for typing tissue cultured date palm plants. Amplification fragment length polymorphism (AFLP), as revealed by randomly amplified polymorphic DNA (RFPD) assay, was utilized to establish the trueness-to-type of *in vitro* cultured date palm cultivars. A set of 164 commercially available decamer oligonucleotides were screened using genomic DNA from Barhee and Khalas date palm cultivars.

Perfecting embryogenic tissue culture techniques for mass production of date palms and other plants

Date palms are prime trees for the arid and semi-arid zones of the Middle East and represent a historically preferred food in Kuwait and the GCC. The research (AboEl-Nil, 1996) carried out concerns the application of tissue culture techniques, or large-scale propagation of superior cultivars, which may lead into the development of the commercial production of dates and its associated activities in Kuwait. Successful micro-propagation of date palms by cell and tissue culture techniques, including callus initiation through embryo formation and germination, adventives embryonic, plantlet growth, acclimatization and utilization of suspension cultures, were carried out. A large inventory of cultures and isolated plants are a valuable outcome of this research. These cultures are being used to produce a large number of plants in a semi-pilot production unit. PCR technology showed the callus and plantlets produced to be identical to the

mother trees of Barhi and Khalas varieties. Plantlets are now growing in the greenhouse and expressing normal morphology. A system for regeneration was developed for suspension cell culture. This system lends itself to mechanization and possible application for selection of somaclonal variants that may possess desirable traits such as salinity tolerance. The findings of this research provide the base for public and private sector development of date palm plant production.

Genetic manipulation of salt tolerance, using the mangrove salt-tolerant genes as a starting base

Recent advances in tissue culture and molecular biology have made it possible to supplement a physical management approach with a biological approach (by genetically adapting plants to saline conditions). It is now technically possible to overcome salinity problems by engineering salt-tolerant genotypes. One pre-requisite for improving salt tolerance by a molecular genetic approach is to identify a system (plants), which grows productively in highly saline conditions. Halophytes represent such a novel system. In this research project (Saleem and Al-Shayji, 1997, Saleem *et. al.*, 2000), exploratory work has been carried out on halophytic (salt-tolerant) plant mangrove (*Avicennia marina*), using tissue culture and recombinant DNA techniques to identify and isolate genes specifying salt tolerance. In a subsequent project, the selected gene(s) will be utilized to produce new improved cultivars of some economically important vegetable crops suitable for the saline environment of Kuwait. This process will, in turn, result in savings of freshwater and will promote brackish water-based agriculture development in Kuwait.

FUTURE STRATEGY FOR BIOSALINE RESEARCH AND DEVELOPMENT

Although several projects were initiated within KISR in biosaline research, much still needs to be considered. The fifth strategic plan of the Institute (2000–2005) (KISR, 2000) continues to support the biosaline research program, particularly in the following areas:

- To improve cultural practices through development, transfer and/or adaptation of technologies for high-priority crops and forages (i.e. tomatoes, cucumber, eggplant, green peppers, melons, onions, potatoes, alfalfa, date palms and perennial grasses) and integration into sustainable production systems.
- To improve the efficiency of meat, egg and milk production through nutritional, genetic and management practices.

- To introduce suitable ornamental and landscape plants, and horticultural practices, for sustained greenery, including optimizing their visual and functional attributes through landscape planning and design.
- To develop, transfer or adapt state-of-art technologies in protected agriculture with emphasis on integrated production, water-use efficiency and fertigation.
- To develop and improve measures for controlling desertification and land degradation through re-seeding, re-vegetation, afforestation, water catchments, and other biological means.
- To conserve and manage related natural resources including vegetation, wildlife, soil and irrigation water, and enhance biodiversity, through utilization of developed and/or transferred technologies.
- To apply genetic engineering for the isolation of stress-specified genes in plants for salt, heat and drought tolerance, and pest resistance in commercial crops.
- To develop tissue culture techniques for the mass production of vegetables, trees and desert plants.
- To develop rapid analytical methodologies for detecting and estimating harmful food and feed contaminants to ensure the safety and wholesomeness of both imported and locally produced material.

ACKNOWLEDGEMENT

The authors extend their thanks and gratitude to the Kuwait Institute for Scientific Research, Kuwait Foundation for the Advancement of Science, Public Authority for Agriculture and Fish Resources, and Islamic Development Bank for sponsoring research projects relating to Biosaline Research.

REFERENCES

Abdal, M., J.N. Sharma and J.J. Rilley. 1990. Halophyte Salicornia (SOS-7) evaluation and development, Phase I (AG-60). Kuwait Institute for Scientific Research. Technical Report.

Abdal, M.S., S.A. Al-Ghawas, A. Shahid and M. Al-Bahou. 1999. An integrated approach for soil reclamation in Kuwait. Preproposal submitted to Kuwait Foundation for the Advancement of Science.

Abdal. M., N. Bhat, N. Al-Ghawas, S. and M. Al-Bahouh. 2000a. Selection of crops for salt-tolerance. (FA011C). KISR 5852. Progress Report No. 1. Submitted to Kuwait Foundation for the Advancement of Sciences. Kuwait Institute for Scientific Research. Kuwait.

Abdal, M., N. Bhat and S. Al-Ghawas. 2000b. Selection of crops for salt-tolerance. (FA011C). Kuwait Institute for Scientific Research. Kuwait.

AboEl-Nil, M.M. 1994a. Introduction of mangrove for protection and enrichment of Kuwait coastlines—Phase I. (FB00K) Proposal. Kuwait Institute for Scientific Research. KISR.

AboEl-Nil, M.M. 1994b. Mangrove introduction along Kuwait's seashore. Proceedings of the workshop on the "Use of sea water in irrigation". Kuwait Institute for Scientific Research, 68–101.

AboEl-Nil, M.M. 1996. Date palm tissue culture development. (AG 66). Kuwait Institute for Scientific Research. KISR.

AboEl-Nil. 1997. Mass propagation of native desert plants. Phase II. Development of tissue culture techniques. (FB010K). KISR 4904r. Kuwait Institute for Scientific Research. Submitted to Kuwait Foundation for the Advancement of Science. Kuwait Institute for Scientific Research. Kuwait.

AboEl-Nil, M., and L. Al-Sabah. 1993. Selection of genes or germplasm suitable for salt tolerance breeding (in three vegetables for Kuwait). Kuwait Institute for Scientific Research. (AG 56). Submitted to Public Authority for Agriculture and Fish Resources. Kuwait Institute for Scientific Research. Kuwait.

Al-Nasser, A. (ed.). 1992. Proceedings of the workshop on the use of sea water in irrigation. Kuwait Institute for Scientific Research. June 4–5, 1992. Kuwait.

Al-Rashed, M. and S. Al-Ghawas. 1999. Optimum use of ground water for sustainable irrigation in Al-Abdally farms. Kuwait Institute for Scientific Research. EH005K Final Report, KISR 5554.

Al-Sarawi, M, E.R. Gundlach and B.J. Baca. 1985. Sensitivity of coastal environments and wildlife to spilled oil and atlas shorelines. Type of resources. Publication of Department of Geology, Kuwait University.

Al-Sulaimi, J., M.N. Viswanathan, M. Naji and A. Sumait. 1996. Impact of irrigation on brackish groundwater lenses in northern Kuwait. Agricultural Water Management. 31:75–90.

Bhat, N.R., H. Al-Zalzalaleh, S.A. Shahid, T. Tahou, H. Minkara and H. Qattan. 2000. Introduction of mangroves for protection and enrichment of Kuwait's coastlines. (FA014C). KISR 5898. Submitted to Kuwait Foundation for the Advancement of Sciences. Kuwait Institute for Scientific Research. Kuwait.

El-Bagouri, Sharma, J.N.; and M. Abdal. 1988. Halophyte Salicornia (SOS-7) Evaluation and Development. (AG 60). KISR 2631. Kuwait Institute for Scientific Research. Kuwait.

Hamdallah, G. 1997. An overview of the salinity status of the near east regions. Proceedings. Regional Workshop on Management of Salt-affected soils in the Arab Gulf States. Abu-Dhabi, UAE. 20 Oct.–2 Nov. 1995. Published by the FAO of the United Nations Regional Office for the Near East Region, Cairo. P. 5.

KISR. 1999. Soil Survey for the State of Kuwait. Volume II: Reconnaissance Survey. AACM International, Adelaide, Australia.

KISR. 2000. The Fifth Strategic Plan. A focused vision for the new millennium. Kuwait Institute for Scientific Research. KISR.

Omar, S.A. 1985. Spring Desert Plants in Kuwait. Environment Protection Council. Kuwait.

Omar, S. A., M. Abdal and J. Sharma. 1987. Conceptual and strategic framework for plant Biosaline and biothermal program development in Kuwait. Kuwait Institute for Scientific Research. Pp. 1–45.

Omar, S.A., T. Madouh, Z. El-Bagouri, Al-Mussalem and H. Al-Telaihi. 1998. Land degradation factors in arid irrigated areas: the case of Wafra in Kuwait. Land Degradation and Development. 9:283–294.

Omar, S.A., Y. Al-Mutawa and S. Zaman. 2000. Vegetation of Kuwait. Kuwait Institute for Scientific Research.

Saleem, M. and Y. Al-Shayji. 1997. Development of Salt Tolerant Plants. Phase I: Identification and isolation of salt tolerance specifying genes from halophytic plants. Proposal (FB006C). KISR 4943. Kuwait Institute for Scientific Research. Kuwait.

Saleem, M., Y.S. Al-Shayji, F. Chellan, F. Al Salameen, S. Al-Amad and D. Albaejan. 2000. Development of salt-tolerant pants. Phase I: Identification and isolation of salt tolerance-specifying genes from halophytic plants. KISR 5933. Submitted to Islamic Development Bank. Kuwait Institute for Scientific Research, Kuwait.

Sharma, J.N., and H. Ibrahim. 1989. Selection of genes or germplasm suitable for salt-tolerance breeding (in three vegetables) for Kuwait. Proposal. KISR 2533B. (AG-56). Kuwait Institute for Scientific Research. Kuwait.

Sharma, J.N., M. AboEl-Nil and H. Ibrahim. 1990. Selection of genes or germplasm suitable for salt-tolerance breeding (in three vegetables) for Kuwait. Progress Report No. 2. (AG-56). Kuwait Institute for Scientific Research. Kuwait.

Taha, F.K. and S.A. Omar. 1988. Range management project Phase II. Assessment of rangelands in Kuwait and improvement for forage animal production and desertification. Vol. IV. Kuwait Institute for Scientific Research. Final report No. 2762.