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Selection of Crops for Sustainable Utilization of Land and Water Resources in Kuwait

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Abstract: Plant growth and yields are decreased by salinity, drought and other environmental stress conditions. Soil salinization is one of man's oldest environmental disasters. The historic records show that many human civilizations declined because of the destruction of crop production by salinization of arable lands. Recent estimates suggest that about 20-25% of the world's irrigated land is destroyed through salinity. Only few crops have moderate salt tolerance and there can be wide variations in salt tolerance among varieties or genetic lines within the same crop species and under different environmental conditions. The combined effects of aridity and soil salinity limit the range of crops that can be grown in Kuwait. Consequently there is considerable government support for research in salinity and drought tolerance in crop and greenery plants. In addition, the present practice of using desalinated sea water to irrigate in Kuwait is an expensive option and hence, research efforts on the use of brackish and treated water for irrigation are the need of the hour. In view of these facts, KISR has conducted several projects in the past two decades to select and promote salt-tolerant plants and technologies for using brackish water. Findings of Kuwait Institute for Scientific Research studies on salinity- and drought-tolerance are presented in this paper.

Key words: Salinization · Salt-tolerant crops · Biosaline agriculture · Drought tolerance · Environmental stress · Water productivity · Water-use efficiency

INTRODUCTION

During the 20th century, the main emphasis of agricultural development all over the world was on increasing productivity per unit area of land used for crop production to feed the ever-increasing population. This was accomplished through over exploitation of natural resources such as water and plant resources and excessive use of fertilizers and pesticides. Although this practice resulted in considerable increase in crop yields in the short-tem, it was not sustainable in the long-run. The productive capacity of the arable land was impaired permanently; the natural water resources were depleted and also polluted with hazardous pesticides and chemical fertilizers to threaten the survival and well being of all life forms on earth. Therefore, the emphasis of agriculture development in the present century is shifted to the sustainable use of land, water and plant resources in agriculture. The major goal of the present day agriculture is to maximize land and water productivity without threatening the environment and natural resources of the country.

Climate of Kuwait: Kuwait is an arid country with extremely hot and dry, extended summers (with an average temperature of 46.2°C), mild winters (with an average temperature of 6.9°C) and scanty erratic rainfall (average 110 mm per year). Strong winds prevail during summer months. Evapotranspiration is very high, ranging from 3.0 to 14.1 mm.d^{-1}. Because evapotranspiration rates (ET) under Kuwait's harsh environmental conditions far exceeds the annual precipitation, supplemental irrigation is crucial for the success of any commercial plant production operation. Additionally, the harshness of the climate and the vulnerability of the resource base in Kuwait, particularly of soil and water, make it essential to thoroughly test and demonstrate the technologies offered prior to recommending them on a commercial scale.

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Land and Water Resources Available for Plant Production in Kuwait: Kuwait's soil is predominantly sandy with low organic matter content and poor moisture- and nutrient holding abilities. Therefore, it is a common practice among agricultural producers and landscape maintenance engineers to apply excess irrigation water to compensate for extreme arid conditions and the lowest water retention capacity of the soil as is evident from data presented in Table 1 (Kuwait Institute for Scientific Research (KISR) [1].

Presently, desalinated seawater and brackish groundwater are mainly used in irrigation in agriculture and greenery sectors. While the cost of desalinated water is very high; ground water supplies are limited and progressively being eroded. Because the annual evapotranspiration far exceeds precipitation, the underground water resources do not get recharged annually through rainfall. Therefore, these water sources do not provide long-term solution for meeting increasing demands for irrigation water in Kuwait. The use of treated waste water, which is available in abundant, is an economically and technically viable option; nevertheless, it must be used efficiently to prevent deterioration of available land and water resources.

Irrigation Induced Salinization of Arable Lands: Soil salinity is a world wide problem but is most serious in arid and semi-arid regions where water is often scarce or unreliable and where ground water tends to be saline. Man-made factors are responsible for saline conditions. While supplemental irrigation has contributed to an increase in agricultural production and greenery development in Kuwait, it adversely affected the long-term sustainability of these activities and has resulted in the degradation of land and water resources in the country. While Kuwait's native soil is non-saline, use of saline water with total dissolved salts ranging from 3,000 to 8,000 ppm under the prevailing extreme arid environmental conditions has resulted in progressive salinization of farm lands, where application of any irrigation water would increase the amount of salts in the soil. This problem is compounded by the following conditions:

- Lack of proper drainage system.
- Calcareous nature of the soil.
- High evaporation from the soil surface.
- Over irrigation.
- Presence of *gatch* layer at the near the soil surface leading to water logging.
- Poor fertilizer management.
- Lack of mulching.

Management Options Under High salinity and Drought Conditions in Arid Climates: In spite of the local harsh climate, progressive salinization of farmlands and poor quality water, Kuwait recognizes the necessity to expand its agriculture production base in order to achieve modest level of food security in respect of fresh food commodities; and improve the living environment. To economically produce plants under these peculiar circumstances, Kuwait has to adopt engineering (installation of drainage systems, leaching of excess salts, improve water-use efficiency and apply water conservation measures) and/ or biological (growing of salt and drought tolerant crops and genetic modification to improve salt- and drought tolerance) options. Where salinity is due to mismanagement of irrigation, soil reclamation usually takes the form of laying underground drainage system and leaching of salts with fresh water. This is largely expensive operation and despite massive efforts, only fraction of the salt-affected areas has been reclaimed all over the world. Since the water used for leaching is rarely re-used, it might contaminate ground water and pose environmental risk. Besides irrigation-induced salinity, removal of plant cover for feeding livestock or other needs in arid regions has also brought a large area under high salinity conditions. In both irrigated and non-irrigated saline lands, fresh water, on which the normal agriculture depends on, is scarce or expensive, whereas saline or brackish water is always available. This could be used for cultivating salt-tolerant plants. Plants have vast genetic variability and more than one-hundred species exhibit salt-tolerance. These plants could be used for food, animal fodder, green manure, industrial products and greenery development. Recent advancements in biosaline agriculture research has opened up enormous opportunities for improving agricultural production in arid regions by indicating that certain crops and genotypes exhibit greater tolerance to salinity than others [2-8]. However, for any tangible increase in crop production and sustainability of crop production enterprise in Kuwait, it is important to introduce and naturalize tolerant crop lines or genotypes for prevailing weather conditions and adapt agro-production practices that would ensure efficient utilization of available water resources.

KISR Research in Salinity and Drought-tolerance: Salinity and drought are usually the most limiting factors

Table 1: Daily Water Requirement of Different of Plants Under Kuwait's Environment

Plant Category	Daily Water Use (liters)
Palms	110 -200
Ornamental Trees	60-100
Afforestation Trees	35-50
Shrubs	20 to 50
Groundcover	12.5 to 25 liters/m^2
Lawn	17.5 to 25 liters/m^2

Source: KISR, 1996

for plant growth under arid environments because stress from any one of these factors can reduce growth much more than all other environmental stresses. These are also major concerns in Kuwait today. While salinization is the occurrence of excessive soluble salts in soils, drought is the absence of rainfall or irrigation for a period of time sufficient to deplete soil moisture and injure plants. Screening of plants for salt- and drought stress tolerance is important for sustainable utilization of available plant materials, land and water resources in plant production.

Although some researchers have attempted to determine the effects of high soil salinity levels on growth and productivity in crop plants, most of these studies were conducted under more moderate climatic and growing conditions. Plants were also not exposed to other stresses (such as salt spray, extreme temperatures and low relative humidity) implying that the findings of these studies can, at best, provide a broad indication about relative tolerance ability of different cultivars to soil salinity only. Therefore, KISR conducted several studies to determine salt- and drought tolerance in selected crop plants.

Selection of Crops for Salt Tolerance. Exploitation of existing genetic diversity has been the basis of all conventional breeding programs. This approach has resulted in the release of improved cultivars of major crop plants worldwide. Therefore, Aridland Agriculture and Greenery Department at KISR has an ongoing program on plant testing program in which potential plants are introduced from places that have similar climatic conditions and tested for their performance under prevailing soil and climatic conditions of Kuwait. Out of these, three projects dealt with the selection of plants for salinity and drought tolerance. A number of methods are currently available for screening for salt-tolerance. Since these techniques have been developed with specific objectives and/or crops or set of conditions, the suitability of these techniques was tested under local environmental conditions. This is important because such studies will provide answers to some of the critical questions raised by the local farmers by generating accurate and reliable information concerning the response of different plants to salt stress.

Two screening methods were utilized, namely, germination and seedling growth in salinized culture solution (the Mchimmie and Dobrenzm technique [9]) and screening at the adult stage as per the procedure suggested by Yourman [10] and Jones [11]. This was followed by a field study, in which salt tolerant genotypes from the laboratory and greenhouse were grown using the available brackish water. These methods were selected taking into consideration the time required to carry them out, the ease of reproducibility with them as well as their reliability in indicating the true nature of salinity tolerance when crops were actually grown in the field.

Parameters used for selecting salt-tolerant lines were germination percentage, days needed for initiation and total germination, seedling growth (height, relative growth rate and fresh and dry weight), plant condition (degree of leaf necrosis and seedling vigor) and yield. In the case of leaf necrosis, a subjective scale of 0 to 5 with 0 being no tip burn and 5 referring to severe leaf browning was adopted. Vigorous seedlings showing good growth and freedom from severe leaf burn were selected for further screening at adult stage. Salinized nutrient solution recommended by USDA Salinity Laboratory was used in the laboratory and greenhouse screening experiments (Table 2).

Out of a total of 1,230 lines of crops screened, 220 were found to be salt-tolerant in the laboratory and greenhouse experiments. Out of these, only 74 were finally selected after the field study (Table 3).

Selection of Salt-tolerant *Zizyphus* Varieties. The main objective of this study was to assess the response of ten improved varieties to irrigation with varying levels of salinity to select salt tolerant varieties for fruit production and greenery development. For this study, grafted plants of ten improved varieties were used. Plants were planted in 15-gal plastic containers filled with agricultural soil and irrigated with freshwater until they were established. Salinity stress was administered by irrigating the plants with salinized nutrient solution containing different amounts of total dissolved solids concentrations (5, 10 or 20 dS/ m). Data on survival, growth and physical conditions were recorded to ascertain the effects of salinity on the growth performance of different cultivars.

Varieties differed in their response salinity with some withstanding total dissolved salts (TDS) of 12,800 ppm in the irrigation without any significant reduction in height

Table 2: Composition of the Complete Nutrient Solution used in the study

Chemicals	Chemical formula	Concentration in nutrient solution
Calcium nitrate	$Ca(NO_3)_2 .4H_2 O$	2.5 mM
Potassium nitrate	KNO_3	3.0 mM
Magnesium sulfate	$MgSO_4. 7H_2 O$	1.5 mM
Potassium phosphate	$KH_2 PO_4$	0.2 mM
Iron as EDTA[x] Complex		6.0 mg /l
Micronutrient solution[y]		0.5 ml /l
Boric acid	$H_3 BO_3$	2860.0 mg /l
Manganese chloride	$MnCl.4H_2 O$	1810.0 mg /l
Zinc sulfate	$ZnSO_4.7H_2 O$	220.0 mg /l
Copper sulfate	$CuSO_4.7H_2 O$	80.0 mg /l
Molybdate	$H_2 MoO_4.H_2 O$	90.0 mg/l

pH of the nutrient solution adjusted to 6 to 7 by adding $H_2 SO_4$.

[x]For iron prepare a stock solution by dissolving 10 grams of Sequestrene 330 per liter and take 6 ml of the stock solution per liter of nutrient solution.

[Y] Hoagland micronutrient solution.

Table 3: Selection of Crops for Salt-Tolerance[*]

Crops[**]	Lines Tested	Tolerant Lines in GH study	Tolerant Lines in the Filed Study
Barley	332	76	10
Cabbage	106	15	10
Cauliflower	103	13	10
Garlic	28	26	12
Onion	103	45	10
Others	558	58	22
Total	1,230	220	74

[*]Response of genotypes to salinity was tested using salinized Hoagland nutrient solution at germination and growth under greenhouse and field conditions.

[**]Genotypes (lines) tested were received from various international organizations

Table 4: Height growth of Five *Zizyphus* Varieties as Affected by Salinity of Irrigation Water

Salinity (ppm)	Bangladesh selection	Musky	Thailand selection	Kuwait selection	UAE selection
3,200	24	51	195	68	43
6,400	25	114	175	39	48
12,800	8	44	139	25	41

Table 5: Response of Selected Ornamental Plants to Salinity

	Height growth (%) in 12 Months				
Salinity Levels	*Peltophorum ferruginum*	*Thespeisia populnea*	*Ficus pumila*	*Duranta goldiana*	*Allamanda cathartica*
Fresh water	25	13	41	186	65
2.5 dS/ m	41	38	63	178	25
5.0 dS/ m	46	20	79	177	45

growth, while others were affected by TDS above 6,400 ppm. However, greenry impact of these varieties were adversely affected at the highest salinity level (12,800 ppm TDS). The effects of salinity on the height growth of five most promising varieties are shown in Table 4.

Selection of Salt-tolerant Ornamental Plants: Response of ornamental plants to saline irrigation water was ascertained in one of the ongoing projects in AAGD. Experimental plants were planted in 15-gal plastic containers filled with agricultural and irrigated with salinized nutrient solution containing different amounts of total dissolved salt concentrations (1,000, 1600 or 3,200 ppm TDS). A complete randomized block design with three replications was used for ascertaining salt tolerance of the different species. Data on survival, growth and physical conditions were recorded to ascertain the effects of salinity on growth of different species.

The height growth of five salt tolerant plant species in different salinity treatments is presented in Table 5. Based on preliminary data, *Allamanda cathartica*, *Duranta goldiana*, *Peltophorum ferrugina*, *Ficus pumila* and *Thespisia populnea,* were found to be appeared to be highly tolerant to salinity (Table 6). Growth in other species were affected only slightly by the highest salinity (5.0 dS/ m) treatment [8].

Selection of Drought-Tolerant Ornamental Plants: Salinity and drought are now the major determinants of global plant production as millions of acres of arable land are lost from production each year due to these causes. While salinization is the occurrence of excessive soluble

Table 6: Response of Selected Plants to Induced Water Stress

	Height Growth (%) in 12 Months				
Soil Moisture (%)	*Peltophorum ferruginum*	*Thespesia populnea*	*Ficus pumila*	*Duranta goldiana*	*Clerodendron thomsone*
<2	3	3	83	84	36
2 -4	16	11	150	122	206
4-6	11	3	93	101	110

salts in soils, drought is the absence of rainfall or irrigation for a period of time sufficient to deplete soil moisture and injure plants. Based on their response water stress, plants are classified as drought sensitive or tolerant plants. Drought symptoms resemble salt stress because high concentrations of salts in the root zone also cause water loss from roots. Salt- and drought tolerant plants maintain their turgor at low water potential by increasing the number of solute molecules in the cell.

Containerized Plants of Species Listed in Table Will Be Used for the Study: Test plants were transplanted in 15-gal plastic containers filled with agricultural soil. Test plants were irrigated to field capacity until they were established in these containers [8]. Following their establishment, irrigation stress was administered by irrigating the plants at predetermined soil moisture depletion levels (no stress control, 50 % moisture depletion i.e., 2 -4% moisture or 75% moisture depletion). Tensiometers were used for determining the time of irrigation in different treatments. Fresh water was used for irrigation this experiment. Height growth of five ornamental plants under different levels of induced stress is presented in Table 6. While it is feasible to wait until 75% moisture depletion, irrigating plants when the soil moisture was depleted by 50% increased the growth in these plants.

Utilization of Native Plants for Sustainable Greenery Development: Most introduced ornamental plants demand increased maintenance and utilize enormous quantities of irrigation water in addition to other production inputs such as fertilizers and pesticides. Use of excess fertilizers and pesticides pollute the environment. Because they are best adapted to local climatic and soil conditions, use of native plants in landscape projects can be highly beneficial in conserving limited resources. Blending native with introduced species in the local landscape also promote wildlife biodiversity and sustainability. Natural landscaping is an opportunity to reestablish and enrich diverse native ecosystem while at the same time provides a natural look to parks and gardens reflecting the national heritage and culture.

CONCLUSIONS

For developing sustainable agriculture in the 21st century, the economic and environment productivity should be increased in the plant production sector. For any plant production activity to be sustainable, it is important to conserve resources, such as land, water and native biodiversity and utilize native plants which are well adapted to local climatic and soil conditions. The use of native plants will also maintain local ecosystem health and preserve the national heritage of the country. KISR research has proven that there is a good potential for developing salt-tolerant crop lines through conventional and non-conventional approaches. Furthermore, techniques that enhance water and land productivity (mulching, recirculation of irrigation water) are important to improve water-use efficiency in plant production [6, 12, 13]. The outcome of KISR research would facilitate the development of sustainable agriculture in Kuwait.

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