European Journal of Scientific Research
ISSN 1450-216X Vol. 29 No.4 (2009), pp. 543-548

http://www.eurojournals.com/ejsr.htm

Response of *Zizyphus* Varieties to Irrigation Water Salinity Under Arid Climatic Conditions of Kuwait

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Abstract

Continuous irrigation with brackish water without proper water management practices has resulted in severe salinity problems in crop production in Kuwait. Therefore, salt-toler¬ance response of ten *Zizyphus* varieties was assessed in this study. Experimental plants were irrigated with nutrient solutions of 5, 10 or 20 dS/ m of electrical conductivity. Periodic data on vegetative growth, physical plant conditions and nutrient availability in soil and leaves showed that all the *Zizyphus* varieties tested in this study can be grown with saline water irrigation. However, their growth and physical plant conditions was adversely affected when the irrigation water salinity was greater than 10 dS/ m (6,400 ppm TDS). Varieties, such as Thailand Selection and Kuwait Selection 2 seemed to have greater tolerance to saline water irrigation than other varieties. Pakistan Selection 2 and Tufai Red were highly sensitive to salinity.

Introduction

Open field agriculture in Kuwait is faced with challenges such as extremely high summer temperatures, low relative humidity, strong winds, rapidly depleting groundwater resources and highly saline irrigation water. Because of high costs of desalination and delivery of freshwater supplies to designated agriculture areas, farmers rely on the use of brackish water for irrigation. Like in several other arid and semiarid countries, perennial irrigation with brackish water without proper water management practices has resulted in severe salt buildup in the soil. Therefore, irrigation-induced salinization has become a widespread problem in irrigated agriculture in Kuwait. Consequently, application of simple, efficient salinity management strategies, such as use freshwater to leach excess salts from the root zone and use of salt-tolerant crops/ lines have become increasingly important.

Salinity tolerance of various fruit crops, including *Zizyphus*, has been investigated by several researchers (Dhankar et al., 1978; Patil and Patil, 1983; Maas, 1984; Hooda et al., 1990; Singh and Singh,1994). While all *Zizyphus* species showed a greater degree of tolerance to soil salinity than other fruit crops, *Z. rotundifolia* had the maximum tolerance to high soil salinity (electrical conductivity values up to 20.25 dS/m) and sodicity levels (Exchangeable sodium percentage of 60.5). On the other hand, *Z. mauritiana* grew well under moderate sodicity and salinity levels (ESP < 35; pH < 9; and ECe < 4) (Singh and Singh, 1994; Awasthi et al., 1997). As these studies were conducted under moderate climatic conditions, the plants were not subjected to other stresses (such as high temperatures and low relative humidity), implying that the findings of these studies can, at best, provide a broad indication about the relative tolerance of the different cultivars to soil salinity only. Therefore, the salt-tolerance response of ten *Zizyphus* varieties was determined under coastal conditions of Kuwait.

Materials and methods

Climatic Conditions

Kuwait is a small, flat to gently undulating desert country extending between latitudes 28° 33' and 30° 05' N and longitudes 46° 33' and 48° 30' E in the north-eastern part of the Arabian Peninsula. The climate is classified as hyperarid (precipitation / potential evapotranspiration = < 0.05) and is characterized by extremely hot dry summers with long, intense sunshine hours and moderately cool short winters with occasional rain (Middleton and Thomas, 1997). The average daily maximum and minimum temperatures varies between 18.9°C during January and 46.8°C in July and between 8.2°C during January and 28.30C during July (Annual Statistical Report, 2006). The rainfall which occurs anytime between mid October and late April, is minimal; averaging about 115 $mm.y^{-1}$ (fluctuates between 25 and 250 mm), but the evaporation is very high, ranging from 3.1 to 21.6 $mm.d^{-1}$. The relative humidity is low and, strong, dry and hot northwesterly winds prevail during summer, particularly in June and July. Weather conditions during the investigation were harsh and fluctuated considerably.

Plant materials and planting

Ten improved varieties of *Zizyphus mauritiana* grafted on *Zizyphus spina-christi* were used in the study. These plants were transplanted into 15-gal polyethylene containers filled with available sandy loam soil. A representative sample of the soil used in the study was analyzed for various chemical parameters (Table 1). Test plants were irrigated with freshwater until they were fully established in these containers.

Table 1: Chemical analysis of the soil used in the salinity study

Parameter	pH	ECe (dS/m)	Cations (meq/l)		Anions (me/l)		
			Ca^{2+}	Mg^{2+}	$CO3^{-2}$	HCO_3^{-1}	Cl^{-1}
Prior to Planting	7.5	3.6	30.7	7.0	0.0	1.4	12.1
Prior to Initiation of Salinity Treatments	7.6	1.1	5.8	1.5	0.0	4.1	3.6

ECe = Electrical conductivity; Soil samples were analyzed using Page et al., (1992) procedures.

Treatment details

Salinity stress was administered by irrigating the plants with salinized nutrient solution containing 5, 10 or 20 dS. m^{-1} (3,200, 6400, or 12,800 ppm of total dissolved salts, respectively). The nutrient compositions of salinized solutions were as per the United States Salinity Laboratory's specifications (Hoagland and Milazzo, 1950). The salinized solutions of a desired electrical conductivity (EC) were prepared by adding appropriate amounts of NaCl and $CaCl_2$ to the nutrient solution. A complete randomized block design with three replications was used for the study.

Chemical analysis of soils and plant samples

Soil and plant samples were collected from different salinity treatments at two month intervals. These samples were analyzed for various chemical parameters using the recommended procedures (Page et al., 1982).

Data recording and analysis

Data on surviv¬al, growth and physical conditions were recorded at two month intervals to ascertain the effects of salinity on growth performance of different cultivars/lines. The data were analyzed using the ANOVA procedures and significant treatment means were identified using the Duncan's Multiple Range Test (Little and Hill, 1978).

Results and Discussion

Vegetative growth

While there was no plant mortality in any of the salinity treatments, varieties differed in their responses (Tables 2). Response to irrigation water salinity varied with both the varieties and salinity levels. Plants in the highest salinity treatment (20 dS. m^{-1}) grew at slower rates than those in the other two treatments (5 and 10 dS. m^{-1}). The height growth in varieties such as Tufai Red and Pakistan Selection 2 were most affected by salinity. In contrast, stem diameter was not affected by salinity treatments.

Table 2: Relative growth rate in height and stem diameter of ten improved *Zizyphus* varieties in the three salinity treatments

Varieties	Plant Height Growth Rate %			Stem Diameter Growth Rate %		
	5dS/m	10 dS/m	20 dS/m	5dS/m	10 dS/m	20 dS/m
Kuwait Selection 1	98.2	119.2	99.4	87.1	103.2	103.2
Musky	50.9	114.1	44.1	53.7	68.3	68.3
Bangladesh Selection	24.6	55.4	8.1	46.3	41.5	41.5
Pakistan Selection 2	55.1	54.9	48.1	35.7	45.2	45.2
UAE Selection	42.4	48.1	41.5	84.4	57.8	57.8
Kuwait Selection 2	68.0	38.8	24.5	66.7	78.6	78.6
Asly	27.5	35.2	43.7	139.1	165.2	165.2
Thailand Selection	195.6	175.8	169.0	106.1	97.1	97.1
Tufai Red	35.7	57.5	10.7	27.3	12.5	12.5
Pakistan Selection 2	41.4	41.2	43.6	40.5	59.5	59.5
Significance variety (V)	*				*	
Significance salinity levels (L)	*				*	
Significance V X L	NS				NS	

Physical condition

Plants in the highest salinity treatment (20 dS. m^{-1}) had the least visual impact. The salinity effects were manifested through change in foliage color towards yellowish green and reduced plant vigor.

Chemical analysis of soil and plant samples

Irrespective of varieties, soils that were irrigated with highly salinized water (20 dS/ m) accumulated greater amounts of Na, Cl, Ca and K (Tables 3). This indicates that continuous irrigation with salinized water resulted in salt build up in the soil.

Table 3: Nutrient levels in the growing media after 480 days of planting in the three salinity treatments.

Salinity levels dS/m	pH	ECe mS/cm	Nutrient levels mg/l										
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	P	Cu^{++}	Fe	Zn^{++}	Cl -	B	NH_4^{+}
5	7.8	1.17	97.00	17.40	144.06	23.53	0.47	0.03	<0.05	0.02	210.34	0.09	0.10
10	7.8	1.77	135.00	16.80	235.43	13.57	0.25	0.03	<0.05	0.02	442.87	0.09	0.14
20	7.6	3.42	218.00	16.80	497.29	28.83	0.30	0.02	<0.05	<0.01	1016.19	0.14	0.29

It is interesting to note that certain varieties were able to absorb significant amounts of potassium even when they were irrigated with 20 dS. m^{-1} salinized water (Table 4). That is why they are able to tolerate higher salt contents in the soil and/ or irrigation water.

Table 4: Effects of Salinity Levels on Nutrient Levels in Leaves of *Zizyphus* Varieties 480 days After the Start of the Salinity Treatments

Varieties	Salinity Levels (dS/ m)	Nutrient Levels (mg/kg)									
		Ca	Mg	Na	K	P	Cu	Fe	Zn	B	N %
Thailand Selection	5	18,076	2,831	333	20,736	1,365	12.0	257.5	20.5	52.8	2.3
	10	18,196	2,996	315	19,569	1,988	18.9	503.0	35.8	31.5	4.0
	20	20,168	2,126	343	22,611	1,788	15.5	343.0	25.0	27.8	3.4
Kuwaiti Selection 2	5	21,574	3,074	398	18,034	1,700	21.3	571.0	30.0	35.8	3.1
	10	17,796	2,641	383	18,711	1,333	21.3	765.0	75.5	33.0	2.5
	20	23,151	2,886	448	18,586	1,475	23.3	555.0	27.0	26.3	2.9
Tufai Red	5	24,914	2,726	488	17,271	1,372	18.5	526.5	26.8	30.5	2.7
	10	20,924	2,264	518	16,751	1,545	17.3	332.0	24.5	21.0	3.2
	20	16,766	2,321	515	9,284	2,498	14.3	305.5	19.8	24.6	2.6

The results of this study suggest that all varieties tested in this study were able to withstand high salt concentrations in the irrigation water. Dhankar et al., (1978) also observed that *Zizyphus* plants are sensitive to high salinity stress in the germination stage, but its tolerance response to high soil salinity increased with the age of the seedlings. These researchers showed that the shoot extension and stem diameter were independent factors against salinity, with the height growth being more sensitive to high salinity than the radial growth. Furthermore, the salinity effects are most pronounced during the extreme weather conditions.

Conclusions

Periodic data on vegetative growth, physical plant conditions, nutrient availability in soil and nutrient levels in leaves showed that all the *Zizyphus* varieties tested in this study can be grown with moderately saline irrigation water. However, their growth and greenery effect will be adversely affected when the irrigation water salinity is greater than 10dS. m^{-1}. Under the harsh arid environmental conditions of Kuwait, varieties, such as Thailand Selection and Kuwait Selection 1 appeared to have greatest tolerance to saline water irrigation whereas Kuwait Selection 2, Bangladesh Selection and Tufai Red were most sensitive.

Acknowledgement

The authors would like thank Kuwait Foundation for the Advancement of Sciences, and Kuwait Institute for Scientific Research for their financial support and encouragement.

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