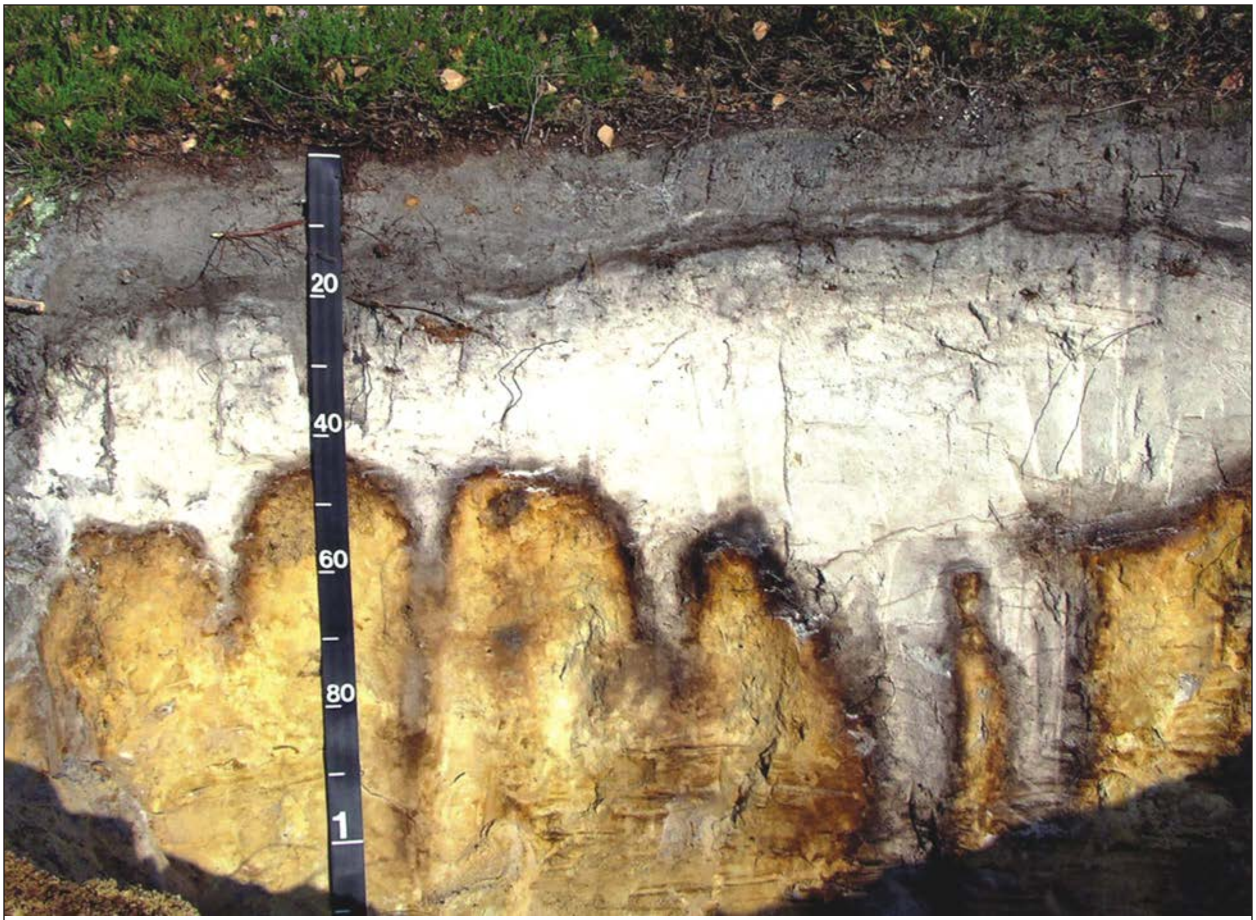

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Research Article
Re-using Diluted Reverse Osmosis Brine Water on the Growth of Two Varieties of Onion (*Allium cepa* L.)

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Abstract

Background and Objective: High water demand which intensified the problem of water shortage enforced the decision maker for looking to new non-conventional water resources. The objective of this study was to discover the effect of using diluted reverse osmosis (RO) brine (reject) water on the growth of two onion (Allium *cepa* L.) varieties. **Materials and Methods:** The research work was conducted with two cultivars: 'Giza 20' and 'Grano Texas' during the period of 2011/2012 and 2012/2013 growing seasons. Twelve similar seedlings of each cultivar were planted in eighty four pots. Six levels of salinity were applied to the plant: Control (tap water with EC = 0.5 dS m^{-1}), 1, 2, 3, 4 and 5 dS m^{-1}.The treatments (onion cultivars and different levels of salinity) were laid out in a randomized complete block design with 7 replications. Each treatment and replication was conducted in a separate pot. During different stages of crop growth, data of different parameters were recorded 3 times at an interval of 30 days starting after transplanting. Data were analyzed by two way ANOVA and SAS. **Results:** Higher water salinity significantly $p<0.05$ reduced plant height, number of leaves/plant, neck diameter, plant fresh weight, bulb fresh weight, bulb length and diameter and dry matter content of the bulb in both cultivars in Jordan. 'Grano Texas' variety produced significantly higher yield than 'Giza 20' at all diluted brine water used. Increasing water salinity did not increase the concentration of several nutrients in the plant leaves except for magnesium while decreased the accumulation of copper and lead by leaves while, sharply increased in electrical conductivity, calcium, magnesium, sodium, total cationic ions, sodium absorption ratio and exchangeable sodium percentage in the soil due to irrigation with water which has the salinity up to 4.0 dS m^{-1}. **Conclusion:** Onion varities with higher tolerant to saline water such as 'Grano Texas' onion can be irrigated with RO brine water.

Key words: Brine water, reverse osmosis, salt stress index, salinity, *Allium cepa*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Industrialization and dramatic demographic increase in the last decades resulted in a high water demand which intensified the problem of water shortage[1]. Available water resources in the Mediterranean basin especially Jordan are expected to decline by 2020[2]. In Jordan, water demand exceeding the available fresh water supply due to increase population and economic growth. This problem is intensified with the arrival of refugees into the country in recent years. To solve this problem, non-conventional water resources should be implemented. Different source of non-conventional water could be used to replace fresh water for irrigation, such as waste water, saline water and grey water[3,4] as well as reverse osmosis reject waters[5]. Irrigation with non-conventional water requires sufficient understanding of how this water affect plant and soil.

Brine water from RO plant, if discharged to the environment will cause environmental contamination to the soil, groundwater and plants. If it is discharged to the sea, it will affect the salinity and aquatic life at the discharge points. From the economic point of view, reuse of this water will reduce the cost of disposal and the cost of environmental rehabilitation to restore its impact[6].

Salinity has significant effects on plant physiological processes such as change and impair basic metabolic processes[7,8] resulting in growth inhibition and yield reduction[5,9] through decreased soil water potential[7,10] which reduce the metabolic activity inside the plant. The deficiency in available water under saline conditions causes dehydration at cellular level. Irrigation with saline water increased the toxic ions which prevent the uptake of useful ions[11].

Salinity disturbs plants growth in different ways like ion toxicity and/or nutritional syndromes. The extent by which one mechanism affects the plant over the others depends on many parameters including but not limited to genotype, plant age, ionic strength, composition of the salinizing solution and the organ in question[12].

Plants can be classified as: Halophytes ('salt plants'-plants grow at high salt concentrations), salt-tolerant non-halophytes (plants grow at moderate salt concentrations) and salt sensitive non-halophytes (plants are sensitive to even low salt concentrations)[13,14]. Salt tolerant plants have the ability to survive and produce biomass under reasonably high salinity in the root zone[15]. Plant acclimatization to salinity are of three different types: Rejection of ions, the tolerance of plants to increase of ions or by avoiding uptake of certain ions[16,17].

Onion (*Allium cepa*) is the member of the genus *Allium* of the family *Alliacease*[18] which is the most widely cultivated bulb species in Jordan under irrigated and rainfed conditions.

Agriculture in Jordan consumes about 70% of the available water resources which fake a series challenge on the water resources. Saline water from RO plants may represent appropriate source of water to irrigate some plants such as onion. This research aimed to evaluate the impact of the RO brine (reject) water on the morphological characteristics growth of two important popular cultivars of onion in Jordan “Grano Texas” and "Giza 20". Currently, little information is available on the salt tolerance of onion cultivars, therefore, the intention of the present study was also to generate information about salt tolerance and yield stability of the two popular cultivars of onion.

MATERIALS AND METHODS

Water samples: Reverse osmosis brine water was taken from the brine stream of a water desalination plant located in the city of Zarqa, Jordan. The plant capacity is 600 $m^3 h^{-1}$. Samples of water were analyzed in triplicate and the results of the analysis are shown in (Table 1). Standard methods for the examination of water and wastewater[19] were used for the analyses of water.

Planting materials: The research work was conducted with two cultivars: ‘Giza 20’ and ‘Grano Texas’ which were available in the local market and are the dominant variety grown in the area at Al-Huson University College, Al-Balqa Applied University, during the period of 2011/2012 and 2012/2013 growing seasons (December-June).

Pot preparation: Onion seeds of each cultivar (Giza 20 and Grano Texas) were sown in a nursery on September 1st and

Table 1: Characteristics of RO brine water

Parameters	Units	Values
pH	-	8.0
EC	(ds cm^{-1})	7.0
TSS	(mg L^{-1})	425.0
TDS	(mg L^{-1})	4460.0
TH	(mg $CaCO_3$ L^{-1})	2850.0
Ca	(mg L^{-1})	428.9
Mg	(mg L^{-1})	427.2
Cl	(mg L^{-1})	1869.4
Na	(mg L^{-1})	1300.5
K	(mg L^{-1})	26.1
NO_3	(mg L^{-1})	161.1
PO_4	(mg L^{-1})	0.0
SO_4	(mg L^{-1})	571.6
HCO_3	(mg L^{-1})	270.0

4th and transplanting took place on November 1st and 10th during 2011/2012 and 2012/2013 seasons, respectively. Clay soil was put in perforated pots (diameter 24 cm, height 25 cm) with average weight of 8 kg.

Twelve similar seedlings of each cultivar were planted in eighty four pots. In order to improve root development, plants were irrigated with tap water to 100% of the pot capacity for 1 week before starting the irrigation with different levels of salinity.

Six levels of salinity were applied to the plant: Control (tap water with EC = 0.5 ds m^{-1}), 1, 2, 3, 4 and 5 dS m^{-1}. Water salinity levels were accomplished by automatically mixing tap water with RO brine water obtained from the water desalination plant.

Design and layout of the experiment: Two cultivars and different levels of salinity were laid out in a randomized complete block design with 7 replications. Irrigation diluted brine water was started after root development stage. Water salinity levels were achieved by mixing tap water with RO brine water obtained from the water desalination plant using automatic salt water maker. Soil water potential was conserved by frequently weighing the pots and an amount of water equal to the weight loss was added for each pot to achieve 100% of pot capacity. Each treatment and replication was conducted in a separate pot. The plants were irrigated when it was necessary with equal of water from each treatment to reach 100% pot capacity.

Data collection: During different stages of crop growth, data of different parameters were recorded 3 times at an interval of 30 days starting after transplanting.

The plant height was measured from the neck of the bulb to the tip. The number of leaves and the longest one were taken. Neck diameters of four randomly selected plants were measured with calipers at the middle portion of the necks and the average diameter was documented in centimeter.

In order to obtain the plant fresh weight, two plants were harvested from each pot 30, 60 and 90 days after transplanting and weighted.

After harvest, four plants were randomly selected from each pot to determine the bulb fresh weight. The top of the plants were removed keeping only 1.5 cm from the bulb. The bulbs were weighed by an electronic scale (B/C Series, Hong Kong) to achieve accurate weight of the bulbs and the average was calculated and expressed in grams.

Length of harvested bulbs was measured from the bottom of the bulb to the upper cut portion of four randomly selected bulbs from each pot and their average length was determined. Also, the diameter of the bulb for four plants was measured with caliper at the middle portion of the pulp.

Immediately after harvest, the bulbs were cleaned and 10 g of each bulb was weighed from randomly selected bulbs and cut into small pieces. The bulbs were air dried by using envelops under laboratory conditions. These samples were dried in oven at 60°C for 72 h. After drying they were weighed and the percentage of bulb dry matter was calculated.

Plant analysis: All plant analysis was conducted according to test methods[20].

Salt stress index: To assess the effect of diluted brine water levels on the two onion varieties, stress indices were applied using the following Eq[21]:

$$\text{Yield stability index (YSI)} = \frac{Y_S}{Y_P}$$

$$\text{Yield index (YI)} = \frac{Y_S}{\bar{Y}_S}$$

$$\text{Stress tolerance index (STI)} = \frac{Y_P Y_S}{\bar{Y}_P^2}$$

$$\text{Geometric mean productivity (GMP)} = \sqrt{Y_P Y_S}$$

$$\text{Stress susceptibility index (SSI)} = \frac{(1 - Y_S / Y_P)}{(1 - \bar{Y}_S / \bar{Y}_P)}$$

$$\text{Mean productivity (MP)} = \frac{(Y_P + Y_S)}{2}$$

$$\text{Tolerance index (TOL)} = Y_P - Y_S$$

Where:

Y_S = Yield of onion cultivar under stress (saline) conditions
Y_P = Yield of onion cultivar under non-stress (tap water) conditions
$\bar{Y}_S$ = Mean yields of all cultivars under stress conditions
$\bar{Y}_P$ = Mean yields of all cultivars under non-stress conditions.

Statistical analysis: Statistical analyses were analyzed using two way ANOVA and least significant difference test (LSD), with regards to the effects of different irrigation methods using SAS statistical software version 9. Means were compared using the least significant difference test at a level of confidence of $p<0.05$[22].

RESULTS

Analysis of variances: Table 2-6 present the analysis of variances of the effects of different water dilution on the different studied characteristics (plant height, number of leaves, neck diameter, plant fresh weight, individual weight of bulb, length of bulb, diameter of bulb and the percentage of dry matter content of bulb) of two onion varieties.

Effect on the plant height: The differences in the average plant height for 'Grano Texas' and 'Giza 20' varieties of onions at different water dilution levels are represented in Table 2. The plant height was significantly taller in plants irrigated with water that has a salinity of 0.5 dS m^{-1} (control) after 30, 60 and 90 days of transplanting than other treatments, followed by 1 dS m^{-1} salinity level. The plant height decreased gradually with increasing salt concentration reaching to the minimum at salinity concentration of 5 dS m^{-1} which indicated significant effect of salinity stress on the plant height. Plant height irrigated with water that has a salinity of 5 dS m^{-1} were 37.2 and 34.27% shorter than water that has a salinity of 0.5 dS m^{-1}(control) after 90 days at 2011/2012 and 2012/2013, respectively.

'Giza 20' plants were significantly taller than 'Grano Texas by 21.84 and 26.4% after 90 days at 2011/2012 and 2012/2013, respectively as well as at all stages after transplanting in both growing seasons. The interaction effect between onion cultivars and salinity levels in respect to plant height appeared to be insignificant (Table 2), indicating that plant height of both cultivars was reduced with increasing salinity. In fact, the interaction was insignificant for all the vegetative growth parameters tested, indicating that the salinity reduced the vegetative growth uniformly for both onion cultivars and during both seasons.

Effect on the number of leaves: Brine water stress influenced the number of leaves produced by plants in both growing seasons and for both varieties significantly (Table 3). Irrigation with water has salinity levels of 5 dS m^{-1} reduced the number of leaves (compared to control samples) by 46.6, 42.6 and 37.6% after 30, 60 and 90 days, respectively. It was found that the percentage of reduction decreased with time for all salinity levels. The differences in the number of leaves/plant were significant according to LSD 0.05, except, after 90 days in season 2011/2012.

At the first growing season, 'Grano Texas' plants produced significantly more leaves (3.04, 4.33) than 'Giza 20' (2.5, 3.83) at 30 and 60 days after transplanting while at the second growing season 'Grano Texas' plants produced significantly more leaves than 'Giza 20' at all sampling dates.

Effect on neck diameter: Experimental results showed that irrigation with saline water significantly in both growing seasons sampled after 30, 60 and 90 days of transplanting (Table 4). Irrigation with water of 5 dS m^{-1} salinity resulted in reductions ranged from 50% after 30 days in the first growing season to about 18% after 90 days in the second growing season compared to control (tap water with EC = 0.5 dS m^{-1}). Similar to the number of leaves, the percentage of reduction decreased with time.

Table 2: Average plant height (cm) as affected by salinity level treatments and two onion cultivars and their interaction during 2011/2012 and 2012/2013 seasons

	Seasons					
	2011/2012			2012/2013		
Sampling time (DFT)	30	60	90	30	60	90
Variety						
Grano Texas	22.3^{b}	28.49^{b}	45.18^{b}	21.45^{b}	27^{b}	45.45^{b}
Giza 20	22.91^{a}	30.87^{a}	55.05^{a}	24^{a}	33.7^{a}	57.45^{a}
F-test	*	*	*	*	*	*
LSD 0.05	0.59	2.29	1.59	0.70	1.99	1.38
Salinity level (dS m^{-1})						
0.5	27.37^{a}	42.25^{a}	64.5^{a}	28.75^{a}	41.88^{a}	62.38^{a}
1	26.38^{a}	38.5^{ab}	56.62^{b}	26.5^{b}	37.25^{b}	57.75^{b}
2	24.88^{b}	34.37^{b}	49.6^{c}	26^{b}	34.75^{b}	53.12^{c}
3	21^{c}	28.75^{c}	45.25^{d}	20^{c}	30.25^{c}	50.62^{d}
4	18^{d}	18.62^{d}	44.12^{d}	19.38^{c}	17.38^{d}	43.88^{e}
5	15^{e}	15.6^{d}	40.5^{e}	15.75^{d}	16.62^{d}	41^{f}
F-test	*	*	*	*	*	*
LSD 0.05	1.28	4.32	2.76	1.22	3.45	2.38
Interaction						
A×B	NS	NS	NS	NS	NS	NS

*NS indicate significant difference at 5% probability level and no significantly, respectively. Values with same letter in column differ non-significantly (p<0.05)

Table 3: Average number of leaves as affected by salinity level treatments and two onion cultivars and their interaction during 2011/2012 and 2012/2013 seasons

	Seasons					
	2011/2012			2012/2013		
Sampling time (DFT)	30	60	90	30	60	90
Variety						
Grano Texas	3.04[a]	4.33[a]	6.95[a]	4.04[a]	4.79[a]	6.88[a]
Giza 20	2.5[b]	3.83[b]	6.29[a]	2.71[b]	3.66[b]	5.5[b]
F-test	*	*	NS	*	*	*
LSD 0.05	0.37	0.35	0.67	0.36	0.45	0.52
Salinity level (dS m^{-1})						
0.5	4.12[a]	5.38[a]	8[a]	4.5[a]	6[a]	8.5[a]
1	3.25[b]	4.5[b]	6.88[ab]	3.75[b]	4.88[b]	7.38[b]
2	2.62[bc]	3.88[c]	6.75[ab]	3.38[bc]	4.75[b]	7.13[b]
3	2.38[c]	3.75[c]	6.25[b]	3.12[bcd]	3.38[c]	4.88[c]
4	2.25[c]	3.62[c]	6.12[b]	2.88[cd]	3.25[c]	4.62[c]
5	2[c]	3.37[c]	5.75[b]	2.62[d]	3.12[c]	4.5[c]
F-test	*	*	*	*	*	*
LSD 0.05	0.64	0.60	1.21	0.64	0.78	0.91
Interaction						
A×B	NS	NS	NS	NS	NS	NS

*NS indicate significant difference at 5% probability level and no significantly, respectively. Values with same letter in column differ non-significantly ($p<0.05$)

Table 4: Average neck diameter (cm) as affected by salinity level treatments and two onion cultivars and their interaction during 2011/2012 and 2012/2013 seasons

	Seasons					
	2011/2012			2012/2013		
Sampling time (DFT)	30	60	90	30	60	90
Variety						
Grano Texas	0.40[a]	0.69[a]	1.01[a]	0.48[a]	0.66[a]	1.30[a]
Giza 20	0.39[a]	0.64[b]	0.95[b]	0.44[b]	0.61[b]	0.99[b]
F-test	NS	*	*	*	*	*
LSD 0.05	0.017	0.03	0.03	0.02	0.03	0.02
Salinity level (dS m^{-1})						
0.5	0.52[a]	0.76[a]	1.09[a]	0.61[a]	0.71[a]	1.26[a]
1	0.47[b]	0.73[ab]	1.06[ab]	0.54[b]	0.68[ab]	1.23[a]
2	0.39[c]	0.68[bc]	1.01[bc]	0.48[c]	0.66[ab]	1.18[b]
3	0.37[c]	0.65[c]	0.96[c]	0.46[c]	0.63[bc]	1.12[c]
4	0.32[d]	0.58[d]	0.89[d]	0.37[d]	0.58[dc]	1.06[cd]
5	0.26[e]	0.55[d]	0.84[d]	0.33[e]	0.55[d]	1.04[d]
F-test	*	*	*	*	*	*
LSD 0.05	0.029	0.05	0.06	0.04	0.06	0.04
Interaction						
A×B	NS	NS	NS	NS	NS	NS

*NS indicate significant difference at 5% probability level and no significantly, respectively. Values with same letter in column differ non-significantly ($p<0.05$)

Neck diameters of the two cultivars were significantly different for both seasons and after all stages (30, 60, 90 days) except after 30 days of the first seasons. Grano Texas cultivar produced bulbs with thicker necks than Giza 20 by about 13%.

Effect on fresh weight: Plant fresh weights irrigated with 0.5 dS m^{-1} water were significantly higher ($p<0.05$) than the other treatments that sampled at different days from transplanting in both growing seasons and for both cultivar onions (Table 5). The percentages of reductions at 90 days were 8.4, 13, 19.6, 28.2 and 35.6% at salinity level of 1, 2, 3, 4 and 5 dS m^{-1}, respectively. Grano Texas cultivar has an average fresh weight higher (+8.7%) than Giza 20 cultivar.

Effect on bulb yield: All bulb growth indicators decreased $p<0.05$ significantly with increasing salinity levels (Table 6).

The percentages of reduction in the bulb fresh weight compared to control were 10.6, 13.2, 20.9, 30.2 and 40.6% in the first season and 9.3, 15.3, 19.7, 33.6 and 41.3% in the second growing season when the salinity levels of 1, 2, 3, 4 and 5 dS m^{-1}, respectively. Length and diameter of bulb as well as percentage of dry matter content of the bulb achieved

Table 5: Average fresh weight (g) of plants as affected by salinity level treatments and two onion cultivars and their interaction during 2011/2012 and 2012/2013 seasons

	Seasons					
	2011/2012			2012/2013		
Sampling time (DFT)	30	60	90	30	60	90
Variety						
Grano Texas	33^{a}	63.6^{a}	92.9^{a}	31.16^{a}	63.2^{a}	90.02^{a}
Giza 20	29.4^{b}	59.9^{b}	82.9^{b}	30^{a}	59.4^{b}	82.13^{b}
F-test	*	*	*	NS	*	*
LSD 0.05	2	2.5	4.68	1.50	2.17	5.49
Salinity level (dS m^{-1})						
0.5	39.25^{a}	68^{a}	105.5^{a}	40.12^{a}	69.13^{a}	105.37^{a}
1	33.75^{b}	64.5^{ab}	96.6^{b}	35.62^{b}	66.25^{ab}	96.38^{ab}
2	32.62^{bc}	63.25^{b}	91.5^{bc}	30.5^{c}	63.38^{b}	91.88^{bc}
3	29.38^{cd}	61^{bc}	86^{cd}	29^{c}	58.62^{c}	83.5^{c}
4	28.5^{d}	58.75^{cd}	78.5^{d}	26.01^{d}	57.12^{dc}	73^{d}
5	23.62^{e}	55.13^{d}	69.25^{e}	22.25^{e}	53.37^{d}	66.4^{d}
F-test	*	*	*	*	*	*
LSD 0.05	3.48	4.32	8.01	2.68	3.77	9.51
Interaction						
A×B	NS	NS	NS	NS	NS	NS

*NS indicate significant difference at 5% probability level and no significantly, respectively. Values with same letter in column differ non-significantly (p<0.05)

Table 6: Average of bulb fresh weight (g), length of bulb (cm), diameter of bulb (cm) and dry matter content of the bulb (%) as affected by salinity level treatments of two onion cultivars and their interaction during 2011/2012 and 2012/2013 seasons

	Bulb fresh weight (g)		Length of bulb (cm)		Diameter of bulb (cm)		Dry matter content of the bulb (%)	
Seasons	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Variety								
Grano Texas	56.74^{a}	61.03^{a}	5.09^{a}	4.79^{a}	5.81^{a}	5.65^{a}	14.19^{a}	14.56^{a}
Giza 20	50.01^{b}	51.77^{b}	4.23^{b}	4.27^{b}	4.56^{b}	4.89^{b}	12.84^{b}	12.75^{b}
F-test	*	*	*	*	*	*	*	*
LSD 0.05	2.62	4.22	0.42	0.46	0.74	0.60	0.72	0.89
Salinity (dS m^{-1})								
0.5	66.12^{a}	70.42^{a}	5.85^{a}	6.23^{a}	7.18^{a}	7.64^{a}	14.59^{a}	14.75^{a}
1	59.12^{b}	63.85^{b}	5.63^{a}	6.05^{a}	6.96^{a}	7.28^{a}	14.27^{ab}	14.26^{ab}
2	57.38^{b}	59.62^{bc}	5.12^{a}	4.46^{b}	5.5^{b}	4.99^{b}	13.71^{ab}	14.03^{ab}
3	52.27^{c}	56.5^{c}	4.12^{b}	3.93^{bc}	4.5^{bc}	4.66^{bc}	13.59^{ab}	13.55^{abc}
4	46.10^{d}	46.76^{d}	3.67^{b}	3.48^{cd}	3.7^{c}	3.71^{cd}	13.03^{bc}	13.12^{bc}
5	39.26^{e}	41.28^{d}	3.57^{b}	3.03^{d}	3.31^{c}	3.35^{d}	11.92^{c}	12.24^{c}
F-test	*	*	*	*	*	*	*	*
LSD 0.05	4.54	7.32	0.73	0.81	1.29	1.04	1.24	1.55
Interaction								
A×B	NS	NS		NS		NS		NS

*NS indicate significant difference at 5% probability level and no significantly, respectively. Values with same letter in column differ non-significantly (p<0.05)

similar to bulb fresh weight. At salinity of 5 dS m^{-1}, the reduction for the three mentioned parameters in the first season was 39, 53 and 18.3%, respectively and 52, 56 and 17% for the second season respectively. Grano Texas had significantly higher individual weight of bulb (+9.8%), length of bulb (+16.2%), diameter of bulb (+21.2%) and percentage of dry matter content of the bulb (+12.3%) compared to Giza 20 in both seasons. The response of yield component to salinity level for both cultivars was similar for both growing season.

Effect on the concentrations of elements in the plant leave: Concentration of various elements in the onion leaves irrigated with various concentration of RO brine water in the season 2012-2013 are shown in Table 7. It can be observed that there has been no significant effect of the different irrigation salinities on the concentration of potassium, phosphorous, magnesium, calcium, manganese, iron and cadmium in the onion leaves. Higher salinities in irrigation water did not increase the concentration of these elements in the onion leaves. High salinity of soil reduces the transport of

Table 7: Effect of salinity level application's on the contents of various elements in leaves of onion plants during 2012-2013 seasons

Salinity ($dS\ m^{-1}$)	K (%)	P (%)	Mg (%)	Ca (%)	Mn (ppm)	Fe (%)	Cu (ppm)	Cd (ppm)	Pb (ppm)
0.5	2.14	0.030	1.52	3.30	48.8	0.09	19.8	0.15	5.48
1	1.61	0.014	1.56	3.61	58.7	0.10	11.6	0.35	6.48
2	1.85	0.018	1.18	3.32	51.1	0.07	17.8	0.55	4.50
3	1.97	0.032	1.20	3.10	59.1	0.10	10.1	0.05	3.49
4	2.11	0.024	1.09	3.31	47.7	0.10	9.6	0.05	2.49
5	2.06	0.034	1.27	3.29	62.0	0.08	10.3	0.30	1.00

Table 8: Effect of salinity on soil properties as affected by salinity level treatments during 2012-2013 seasons

	Salinity					
Parameters	0.5	1	2	3	4	5
Extract EC ($dS\ m^{-1}$)	5.52	5.55	5.70	6.30	15.45	19.73
Ca ($m\ eq\ L^{-1}$)	22.00	24.80	23.40	31.00	55.60	64.80
Mg ($m\ eq\ L^{-1}$)	14.70	20.10	10.40	14.30	44.00	59.90
Na ($m\ eq\ L^{-1}$)	18.80	12.00	17.36	19.47	69.44	78.50
Total cations ($m\ eq\ L^{-1}$)	55.50	56.90	51.16	64.77	169.04	203.20
Na (%)	33.87	21.09	33.93	30.07	41.08	38.63
SAR (%)	4.39	2.53	4.22	4.09	9.84	9.94
ESP (%)	4.84	2.36	4.62	4.45	11.45	11.56
P (ppm)	7.25	9.40	13.29	10.07	5.64	7.52
K (ppm)	321.90	349.70	349.70	312.60	321.90	349.70
Fe (ppm)	5.64	6.38	5.57	6.50	4.72	4.71
Mn (ppm)	7.00	16.90	19.80	7.09	14.50	18.90
Cu (ppm)	1.50	1.60	1.62	1.47	1.78	1.81
Zn (ppm)	0.60	0.89	0.78	0.48	1.55	1.12
Cd (ppm)	0.08	0.09	0.09	0.07	0.11	0.11
Pb (ppm)	0.88	0.98	1.06	1.04	1.12	1.28

potassium from the roots to leaves causing a potassium deficiency. High NaCl uptake competes with the uptake of other nutrient ions, especially K^+, leading to K^+ deficiency. Total amount of heavy metal (Cu, Pb) was decreased in soil with increasing of salinity, but there is no statistically significant difference between them.

Solubility of Cd and its absorption increases by plant in saline soil by formation complexes of cadmium with chloride.

Calcium concentration was not affected by different treatments of diluted water; however, salinities raised up to 2 $dS\ m^{-1}$ reduced the concentration of magnesium.

Table 7 also shows that the concentrations of copper (Cu) and lead (Pb) in onion leaves decreased as the salinity of the irrigation water exceeded 3.0 $dS\ m^{-1}$. Salinity changes the bioavailability of metals in soil and is a key factor in the movements of metals from roots to the aerial of the plant.

Effect on soil: The effect of using different diluted brine water on the concentration of different ions in soil was examined as listed in Table 8. Sharp increase in a number of soil parameters (extract electrical conductivity (EC), calcium, magnesium, sodium, total cationic ions, sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP) was observed as the salinity of the irrigation water was more than 4 $dS\ m^{-1}$. As the salinity of irrigation water is mainly caused by Na, Cl, Mg and Ca, there was a build-up in the concentration of these elements in the soil.

On the other hand, the concentrations of P, K, Fe, Mn and Cd have not shown a change (or a trend) in their concentrations as the salinity of irrigation water increased. This is also should be expected as the concentration of these elements in the irrigation water is low. Increasing the salinity of water to 4.0 $dS\ m^{-1}$ or higher increase in the concentration of copper (Cu), Zinc (Zn) and lead (Pb) in soil. Increase the concentration of these components in the soil is regular with their decrease in the onion leaves.

Salt tolerance indices: To select the best onion variety to be used under saline water conditions, stress indices were calculated for the two onion varieties used and the results were compared. Stress indices are usually used as selection criteria for different plant genotypes under stress and non-stress conditions.

Mean yield of the two varieties in the stressed conditions was reduced by 23% compared to the non-stressed condition, representing that the two varieties experienced a moderate salt stress (Table 9). Bulb fresh weight were 71.05 and 65.48 g for Grano Texas and Giza 20, respectively under non-stressed

Table 9: Mean of pool data of two years (2011/2012-2012/2013) of bulb fresh weight of two onion variety under stressed and non-stressed environments and their corresponding tolerance indices

Variety	Salinity (ds m^{-1})	YP	YS	TOL	SSI	MP	STI	GMP	YSI	YI
Grano Texas	1	71.1	65.8	5.2	0.74	68.4	1.00	576	0.93	1.07
Giza 20	1	65.4	57.1	8.4	1.28	61.3	0.80	494	0.87	0.93
Grano Texas	2	71.1	61.2	9.9	0.97	66.1	0.93	555	0.86	1.05
Giza 20	2	65.5	55.8	9.7	1.03	60.6	0.78	489	0.85	0.95
Grano Texas	3	71.1	56.9	14.2	0.98	64.0	0.87	535	0.80	1.05
Giza 20	3	65.5	52.0	13.6	1.02	58.7	0.73	471	0.79	0.89
Grano Texas	4	71.1	50.9	20.2	0.89	61.0	0.78	506	0.72	1.10
Giza 20	4	65.5	42.0	23.6	1.12	53.7	0.59	424	0.64	0.90
Grano Texas	5	71.1	47.2	23.9	0.81	59.1	0.72	488	0.66	1.18
Giza 20	5	65.5	33.1	32.5	1.20	49.3	0.46	376	0.50	0.82

YS: Yield of onion cultivar under stress (saline) conditions, YP: Yield of onion cultivar under non-stress (tap water) conditions, TOL: Tolerance index, MP: Mean productivity, GMP: Geometric mean productivity, STI: Stress tolerance index, YSI: Yield stability index, YI: Yield index

Table 10: Correlation coefficients between yield of onion cultivar under stress (saline) conditions and non-stress conditions, tolerance index, mean productivity, geometric mean productivity, stress susceptibility index, stress tolerance index, yield stability index and yield index

	YS	YP	TOL	MP	GMP	SSI	STI	YSI	YI
YS	1	0.46^{ns}	-0.95**	0.97**	0.95**	-0.44^{ns}	0.98**	0.98**	0.47^{ns}
YP		1	-0.17^{ns}	0.65*	0.75**	- 0.79**	0.63^{ns}	0.26^{ns}	0.90**
TOL			1	-0.86**	-0.80**	0.23^{ns}	-0.87**	-0.99**	-0.22^{ns}
MP				1	0.99**	-0.58ns	0.99**	0.90**	0.63*
GMP					1	-0.63*	0.99**	0.86**	0.69*
SSI						1	-0.56^{ns}	- 0.28ns	-0.81**
STI							1	0.91**	0.60^{ns}
YSI								1	0.30^{ns}
YI									1

*,**ns indicate significant difference at 5, 1% probability level and no significantly, respectively. YS: Yield of onion cultivar under stress (saline) conditions, YP: Yield of onion cultivar under non-stress (tap water) conditions, TOL: Tolerance index, MP: Mean productivity, GMP: Geometric mean productivity, SSI: Stress susceptibility index, STI: Stress tolerance index, YSI: Yield stability index, YI: Yield index

condition, while reach to 47.18 and 33.05 for the same variety, respectively under stress condition. Grano Texas variety had better performance than Giza 20 for bulb fresh weight under stress and non-stressed conditions (Table 9). The higher tolerance index value was calculated for Giza 20 when the salinity was >3 ds m^{-1} indicating that this genotypes had a greater yield reduction under high level of salt stress condition and higher salt sensitivity, whereas Grano Texas had a lower yield reduction in severe stress condition. Giza 20 had higher value of salt susceptible than Grano Texas genotype and thus considered as genotypes with high salt susceptibility and poor yield stability in both stress and non-stress conditions. Granotexas with the highest values of stress tolerance indexes as a salt stress parameter, in different sites was considered to be tolerant genotypes, whereas Giza 20 with the lowest stress tolerance index was intolerant. Similar ranks for the two genotypes were detected by other salt stress parameters suggesting that these parameters are comparable for choosing variety.

Correlation analysis: To govern the most suitable salt tolerance criteria, correlation coefficients between yield of onion cultivar under stress (saline) conditions and non-stress conditions were calculated (Table 10). The yield under salt-stressed conditions had a very weak but insignificant association with the yield under non-stressed conditions, indicating that high potential yield under optimal conditions does not necessarily result in improved yield in a salinity-prone environment (Table 10). High significant correlations were found between yield under salt stress environment and the salinity indices; mean productivity, geometric mean productivity, stress tolerance index, which indicated that they were better predictors of yield of onion cultivar under stress (saline) conditions and yield of onion cultivar under non-stress (tap water) conditions.

The results showed high significant correlations among some salinity tolerant parameters for bulb yield. A correlation was originated between stress tolerance index and geometric mean productivity and these were correlated with mean productivity positively and not with stress susceptibility index.

Stress tolerance index, geometric mean productivity and mean productivity were correlated with yield under both stress and non-stress conditions, suggesting that these parameters are suitable to monitor salinity-tolerant genotype. The yield stability index was positively correlated with yield of onion cultivar under stress (saline) conditions and negatively correlated with tolerance index and stress susceptibility index, indicating that this index is useful to discriminate salt tolerant and yield stable genotypes.

DISCUSSION

This study wanted to govern: Whether diluted rejected reverse osmosis water can be utilized for irrigation onion plant. Results from this experiment demonstrate the negative influence of non-conventional water for irrigation especially at high concentration. Rejected reverse osmosis water after dilution with irrigated water caused reductions in all growth parameters measured in onion plants. This declines in vegetative growth with increasing reverse osmosis rejected water level occurred in both variety. This is likely due to NaCl limiting water absorption by seedlings.

Reduction in the onion yield was mainly due to reduction in water absorption as a result of osmotic changes around root zone at high salinity level[7,23,24]. Higher salinity levels in the irrigation water could prevent some elements from being absorbed by the onions. Several studies represented the negative influence of salinity on vegetative growth of onion plants and other crops. Salinity decreased some morphological characteristics of onion plants like bulb diameter and weight, root growth, plant height and number of leaves[25]. Plant height of onion plant was affected with salinity and the reduction was greater at salinity of 9.51 dS m^{-1} [26]. Salinity stress significantly influenced the number of leaves. This reduction may be attributed to the small and shallow rooting system of young plants[27]. Comparable result was found where the number of onion leaves decreased significantly by 50% at salinity of 3.7 dS m^{-1} after 45 days, while at salinity of 9.51dS m^{-1}, the leaves weight was 80% less than of the control[26]. Tolerance index for leaf diameter was significant for three factors (cultivar, salinity and their interaction), while leaf amount was significant for the only salinity[28]. Neck diameter was significantly reduced as salinity increased. Sta-Baba *et al.*[26] found that the onion exhibited an initial decline in growth at 3.7 dS m^{-1} water salinity. High levels of salinity in irrigation water have been shown to restrict onion growth which decreased bulb yield[29]. The bulb fresh weight decreased as NaCl increased. The high salinity caused a reduction in onion bulb in comparison with the control ones[26]. Higher salinities in irrigation water did not increase the concentration of these elements in the onion leaves. High salinity of soil reduces the transport of some elements like potassium from the roots to leaves. This may be due to contrasting effects of sodium and calcium on potassium[30]. Excess salinity in irrigated water caused the loss of potassium due to loss of the difference in charge between the inside and outside of the plasma membrane by sodium ions[31]. Elevated NaCl levels in the root medium reduce mineral nutrient assimilation, especially of K^+ and Ca^{2+}, resulting in ion imbalances of K^+, Ca^{2+} and Mg^{2+} compared to Na^+ [32,33]. In saline soils, for many reasons, including heavy metals forming complexes with chloride, exchange of sodium with heavy metals in adsorption sites and less absorption of heavy metals complexes with chloride on soil and clay particles caused increase absorbable form of heavy metals in soil solution[34]. So researchers has reported complexes chloride with heavy metals absorb less in soil particles, at result these complexes remain in soil and absorbability will be increased by plant[35]. It was observed that in a pot experiment, with increasing NaCl, concentration of Cd and Pb increases in soil[36]. Results obtained by researchers showed that salinity with Cl has an effective role in increasing solubility of Cd and its absorption by plant. Increase of Cd absorption is reported in many crops after irrigation with saline water[37-39]. Plant is more tolerant to salinity if it has a more efficient system for the selective uptake of potassium instead of sodium[40]. It was reported that the high soil salinity reduce the concentration of phosphorous in plants[41]. The effect depends on plant and level of salinity[42]. The effects of salinity on plant growth occurs due to osmotic changes outside the root that reduces the plant ability to absorb water[7,23-24] and from the accumulation of salt in the leaves of the plants. The speed of new leaves production and the speed of old leaves' death due to salt accumulation determines whether the plant is salt tolerant or not. Increase salinity in soil is supposed to reduce the uptake of calcium and magnesium[42]. This was true with magnesium in this experiment. The concentrations of some heavy metals in plants at low salinity were more than those found at high salinity[43]. Increasing salinity increases cadmium uptake while lead there was no effect of salt on lead accumulation in plant tissues[44]. A similar result was found concerning the effect of salinity on lead increasing[42].

A positive but non-significant association between yield in stress and non-stress environments[21,45-47]. The indices, MP, GMP and STI were able to identify high yielding onion genotypes in both stressed and non-stressed conditions and these findings are consistent with the other findings[21,48-52]. These parameters were suitable for discriminating the best genotypes under stress and irrigated conditions[48-51,53]. YSI is a useful index to discriminate tolerant from susceptible genotypes due to its negative correlation with TOL and SSI[21,51]. SSI was used as stability parameter to identify drought-resistant genotypes[54]. In this study, Grano Texas had the lowest SSI values and therefore, this variety has low salt susceptibility and high yield stability in both conditions, whereas Giza 20 had the highest SSI value can be considered as variety with high salt susceptibility and poor yield stability in both stress and non-stress conditions. Similar results were reported for stress tolerance evaluation[21,50,52,55].

CONCLUSION

It is concluded that the effect of using diluted RO brine on onion plant was investigated. Results have shown that higher salinity significantly reduced the yield of both onion varieties planted. The effect of salinity on "Grano Texas" cultivar was less than its effect on "Giza 20" cultivar, except for plant height. Tolerance indices for salinity have also shown that "Grano Texas" outperformed "Giza 20" at all salinities studied and especially at higher salinities. Higher irrigation salinities increased the concentration of magnesium and reduced the accumulation of copper and lead in onion leaves. At salinity level of 4.0 dS m^{-1} or higher, there was a sharp increase in electrical conductivity, calcium, magnesium, sodium, total cationic ions, sodium absorption ratio and exchangeable sodium percentage in the soil. It is recommended to use RO brine water with salinity less than 2 dS m^{-1} to irrigate onion. Onion verities with higher tolerant to saline water such as Grano Texas onion can be irrigated with RO brine water.

SIGNIFICANCE STATEMENTS

This study discovers the effects of reusing diluted reverse osmosis brine water on the growth of two varieties of onion (*Allium cepa* L). Selection of cultivars that can provide economical yield after irrigated with brine water may be an efficient tool in resolving the problem of rejected water from reverse osmoses unites. This study will help the researcher to uncover the importance of irrigation with diluted reverse osmosis brine water on plants that many researchers were not able to explore.

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