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Effect of Salinty and Calcium Additions on Growth and Leaf Mineral Content of Manzanillo Olive Transplants

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Abstract

'Manzanillo' olive (*Olea europea* L.) transplants were grown on a sandy loam soil packed in PVC pipe and irrigated with two types of artesian water having 3072 and 5120 mg soluble salts l^{-1} as well as (SAR) values of 8.6 and 13.2, respectively, as compared with tap water (532 mg soluble salts l^{-1} and 2.6 SAR), supplemented with 0, 4, 8 and 12 mM Ca^{2+} as $CaSo_4 2H_2O$. Growth parameters i.e., stem length and shoot, root and total plant dry weights as well as chlorophyll (a & b), and carotene contents and leaf mineral content (N, P, K, Mg, Zn and Mn) were depressed as salinity increased in plants lacking additional Ca^{2+}. Addition of 8 mM Ca^{2+} was more effective in ameliorating the effects of 5210 mg soluble salts l^{-1} salinity and SAR (13.2) than 4 and 12 mM Ca^{2+} supplements, possibly because Ca^{2+} addition led to reduce leaf Cl and Na contents.

Generally, 8 mM Ca^{2+} addition was proved to be the most effective treatment for enhancing transplant growth and improving leaf mineral content under irrigation with both types of artesian water.

Introduction

In North Sinai, Manzanillo is considered the most dominant olive cultivar. Also, the olive grown areas depended on the water of artesian wells for irrigation. Water of these wells is characterized by relatively high salinity and sodicity levels. Although the olive trees are a medium salt tolerant plant (Hassan *et al.*, 1986), transplants at their early stage are susceptible to the severe injury of salt toxicity and sodium adsorption ratio (Taha *et al.*, 1972; Sharaf *et al.*, 1990). The detrimental effects of salinity on citrus growth have been attributed to osmotic stress, ion toxicity, ionic imbalance or a combination of these factors (Lea-cox and Syvertsen, 1993). Therefore, any treatment can alleviate and reduce the adverse effects of salinity on olive transplants can be of great benefit for oliveculture under such conditions.

The beneficial effect of supplemental Ca^{2+} on growth of salt-stressed plants is widely recognized. La Haye and Epstien (1969), showed that adequate Ca^{2+} was a requirement for shoot and root growth in salt-stressed bean (*Phaseolus vulgaris*), adequate Ca^{2+} can exclude or limit Na+ uptake into roots and its translocation from roots to shoots (Cramer *et al.*, 1987). However, some researches have indicated that high soil Ca^{2+} is associated with poor blueberry growth and vigour (Austin *et al.*, 1986). Furthermore, Spiers (1979), on blueberry, found that Ca^{2+} addition was not harmful. Also, Zekri (2004) reported that soil application of calcium including gypsum has been found to reduce the deleterious effect of sodium and improve plant growth under saline conditions.

The aim of this study was to evaluate the ability of Ca^{2+} addition to ameliorate salinity depressive effect on growth and mineral nutrition of Manzanillo olive transplants.

Materials and Methods

This study was carried out during the two consecutive seasons of 1997 and 1998 at the nursery of Faculty of Environmental Agricultural Sciences, El-Arish, North Sinai Governorate. In early February of both seasons, one-year-old Manzanillo olive transplants were planted individually in 40 cm height X 14 cm diameter PVC pipes, each filled with 5 kg of a sandy loam soil, whose physical and chemical characteristics are shown in Table (1-a). Olive transplants were raised by soft wood cutting. They were healthy, nearly in growth vigour, held under natural conditions and irrigated with tap water (532 mg soluble salts L^{-1} and 2.6 SAR) for 2 weeks before treatment. The plants were sprayed three times by 1% urea solution and 0.4% KH_2PO_4 solution, i e. in early March, mid May and mid July. Tween 20 was used as a surfactant at the rate of 0.1% in the spray solutions.

The experiment included 12 treatments (3 water types x 4 calcium concentrations). Therefore, the experiment was a factorial in a completely randomized block design and each treatment was replicated three times on five transplants per plot.

Water types were from artesian wells Abo Sakl (AW1) and El-Taweel, (AW2) as well as tap water (as a control). The water of both artesian wells was pumped from depth of 70 m in El-Arish area of Sinai. The quality of these types of water is presented in Table (1-b). Ca^{2+} concentrations (as $CaSO_4$, $2H_2O$) were 0, 4, 8, 12 mM which added in the irrigation water. The plants were irrigated twice a week for nine months by adding at least one liter of water per container, which was enough to thoroughly leach through the container.

In late September of both tested seasons, plants were removed from the containers for growth measurements and chemical analysis. Each plant was divided into roots and shoots. Stem length and dry weight of stem, roots and total plant as well as shoot/root ratio were determined. Also, leaf chlorophyll content (a & b) and carotene content were determined using Wettstein's method (1957). Samples of 20 leaves were taken (from the third leaf from basal lateral branches of transplants), washed, dried at 70°C for 48 h, then ground to a powder for mineral content analysis. Total N content in leaf dry matter was determined using semi-micro Kjeldahl method, while total Cl- concentration was determined by silver ion titration using a Haake-Buchler (Saddlebrook, New Jersey, USA) chloridometer. Leaf P, K, Ca, Mg, Na, Zn, Fe and Mn concentrations were determined using ash of leaf tissues by Inductively Coupled Plasma (ICP) analysis on a Perkin-Elmer (Norwalk, Connecticut, USA) Plasma 40 machine (Gaines and Mitchell, 1979).

Data recorded in both seasons were subjected to analysis of variance according to Clarke and Kempson (1997) and differentiated using Duncan's multiple range test (Duncan, 1955).

Table (1-a): Physical and chemical characteristics of the experimental soil

Parameters	Value
Particle size distribution	
Sand (%)	71.8
Salt (%)	12.0
Clay (%)	16.2
Textural class	Sandy loam
Chemical analysis	
Organic matter (g kg^{-1})	0.2
$CaCO_4$ (g kg^{-1})	199.2
PH*	8.20
EC (dS m^{-1})**	0.62
Cations**	
Ca^{2+} (meq l^{-1})	3
Mg^{2+} (meq l^{-1})	2
Na^{+} (meq l^{-1})	1.68
K^{+} (meq l^{-1})	0.18
Anions**	
Cl^{-} (meq l^{-1})	1.60
CO_3^{2-} (meq l^{-1})	----
HCO_3^{-} (meq l^{-1})	2.50
SO_4^{2-} (meq l^{-1})	2.76

* in 1:2.5 soil water suspension.
** in soil paste extract.

Results and Discussion

According to the classification system of irrigation water outline in the Agriculture Handbook of United States Department of Agriculture (1954), it is clear that the predicted hazard of salinity in both tested artesian water wells was very high. The predicted hazard of sodicity was low and medium for well (AW1) and well (AW2), respectively. Accordingly, this work will deal with irrigation water sodicity and salinity.

Stem length

Regarding the specific effect of salinity, data in Table (2) reveal that in both seasons, stem length was significantly decreased with increasing salinity than the control. On the other hand, the most depressive effect was always concomitant to the highest salinity (5120 mg L^{-1}) followed by 3072 mg L^{-1} water salinity. This reduction in stem length as a result of water salinity might be attributed to reduction in cell size or the cells

Table (1-b): Chemical analysis of the tested water used for irrigation

Parameters	Tap water	Artesian water (AW_1)	Artesian water (AW_2)
EC dSm^{-1}	0.83	4.8	8.0
Total soluble salts ($mg\ l^{-1}$)	532	3072	5120
PH	8	8.4	8.5
SAR	2.6	8.6	13.2
Cl^- : SO_4^{2-}	1.24	10.0	10.1
Cations ($meq\ l^{-1}$)			
Ca^{2+}	4	6	10
Mg^{2+}	2	18	29
Na^+	4.5	30	58.5
K^+	0.1	0.2	0.4
Anions ($meq\ l^{-1}$)			
Cl^-	2.4	30	61.7
CO_3^{2-}	---	---	---
HCO_3^-	6.25	21.20	30.1
SO_4^{2-}	1.95	3.0	6.1
Water quality^x			
Total salinity	C3	C4	C4
Sodicity	S1	S1	S2

x: According to Agriculture Handbook (1954).

AW_1: Artesian well water from Abo Sakl, El-Arish, North Sinai.

AW_2: Artesian well water from El-Taweel, El-Arish, North Sinai.

number. Similar results were reported by Strogonov (1984) and El-Deeb (2000).

As for the specific effect of Ca^{2+} addition in the irrigation water, data in Table (2) show that the supplemental Ca^{2+} led to an increase in the average stem length, particularly with 8 mM Ca^{2+} followed by 4 mM as compared with 0 mM Ca^{2+} treatment. These findings may lead to the conclusion that the presence of Ca^{2+} is necessary to maintain cell growth and for the continued growth of apical meristems. Similar results have been reported on sour orange seedlings (Zekri and Parsons, 1990) and on blueberry Wright *et al.,* (1992).

Concerning the interaction between salinity and Ca^{2+} addition, data in Table (3) appear that, the addition of Ca^{2+} to irrigation water increased the height of salinity-treated plants. The most effective treatment on stem length of Manzanillo olive transplant resulted from 8 mM Ca^{2+} X (532, 3072 and 5120 mg soluble salts L^{-1}, respectively as compared with 0 mM Ca^{2+} X (532, 3072 and 5120 mg soluble salts L^{-1}, respectively. Thus it can be said that the addition of $CaSO_4$, $2H_2O$ to irrigation water significantly decreased the adverse effect of salinity on shoot growth.

Plant dry weights

Regarding the specific effect of water salinity, data in Table (2) reveal that salinity caused significant reduction in shoot, root and total plant dry weight. As salinity level increased up to 5120 mg L^{-1} this resulted in the highest reduction in these parameters. Salinity and sodicity of irrigation water reduced shoot growth. This reduction may be due partially to excess accumulation of Na^+ and Cl^- in the leaves. These might be attributed to the process of building up the osmotic pressure of the developing cell, by osmotic adjustment of salt accumulation to meet the increasing osmotic pressure of rooting media. The finding of Munns *et al.,* (1982), Zekri and Parsons (1990) and El-Deeb (2002) emphasized these results.

With regard to the specific effect of Ca^{2+} addition, data in Table (2) show that the addition of 4 or 8 mM Ca^{2+}, but not 12 mM to irrigation water reduced the harmful effect on shoot, root and plant total dry weights as compared with untreated transplants (control). The treatment of 8 mM Ca^{2+} was more effective and followed by 4 mM Ca^{2+} and 12 mM Ca^{2+}, respectively. This increase in the dry matter may be attributed to the effect of Ca^{2+} on the enzymatic systems which are responsible for the biosynthesis of organic compounds and that calcium is important in the reduction of nitrates in plant tissues and it is also known to have a role in the nitrogen metabolism of plants. In this concern, Zekri and Parsons (1990) and Wright *et al.,* (1992) found that the plants receiving 10 mM Ca^{2+} grew almost 25% more than those not supplied with additional Ca^{2+}.

Referring to the effect of interaction between salinity and Ca^{2+} additions, Table (3) shows that all dry weight parameters of experimental plants (shoot, root and total plant) were significantly increased due to 8 mM Ca^{2+} X 532 mg salinity L^{-1} as compared with the control. While the least plant dry weight values produced by 12 mM Ca^{2+} X 5120 mg salt L^{-1} salinity, while the other interactions came in between. Similar results have been reported in shoot and/or roots of sour orange (Zekri and Parsons 1990; Wright *et al.,* 1992). Adequate, Ca^{2+} was reported to exclude or limit Na^+ uptake into roots and Na^+ translocation from roots to shoots (Cramer *et al.,* 1987). Also, the addition of Ca^{2+} to the rooting media significantly decreased the adverse effect of NaCl on shoot growth (Zekri and Parsons, 1990).

Shoot : root ratio:

Referring to the specific effect of salinity, Table (2) shows that 3072 mgL^{-1} salinity resulted in highest shoot/root ratio while the least values (1.10, 1.23) were observed with 532 or 5120 mgL^{-1} salinity in both seasons. This result is in agreement with that reported by Omer (1996) and El-Deeb (2000) who stated that shoot/root ratio was reduced with increasing salinity.

With regard to the specific effect of Ca^{2+} addition, data in Table (2) show that in 1997 and 1998 seasons, there was no clear-cut trend on shoot/root ratio. This result may explain some of the results found previously, where the addition of 4 or 8 mM Ca^{2+}, but not 12 mM, to irrigation water produced the highest stimulative effect on shoot or root dry weights.

Referring to the effect of interaction between salinity and Ca^{2+} additions, Table (3) shows that, in both seasons, there was no clear-cut trend on shoot/root ratio.

Chlorophyll and carotene content in leaves:

Concerning the specific effect of salinity, Table (2) shows that in 1997 and 1998 seasons, leaf chlorophyll (a & b) and carotene content were decreased with increasing salinity. The most depressive effect was always concomitant to the highest salinity level (5120 mg L^{-1}). These results are in agreement with those reported by El-Deeb (2002) who observed that leaf pigments content decreased under salinity treatments. The decline in photosynthetic pigments content of salt-stressed plants might be due to the inhibition of chlorophyll synthesis (Patil *et al.,* 1984).

As for the specific effect of Ca^{2+} additions to irrigation water, the results in Table (2) indicate that the additional Ca^{2+} at 8 mM produced stimulative effect on leaf chlorophyll (a & b) and carotene contents as compared with plants not supplied with Ca^{2+}. 4 mM Ca^{2+} came in the second rank followed by 12 mM Ca^{2+} treatment. This increase in pigments of chlorophyll and carotene may be attributed to the promotive effect of Ca^{2+} on the enzymatic systems which are responsible for the biosyntheis of organic compounds.

Concerning the effect of the interaction between salinity and additional Ca^{2+}, data in Table (3) show that the most depressive effect on leaf chlorophyll (a & b) and carotenes content of Manzanillo olive plants was produced by the highest salinity (5120 mg L^{-1}) without Ca^{2+} addition. The addition of 4 or 8 mM Ca^{2+} to irrigation water decreased the adverse effect of salinity on leaf pigments of chlorophyll and carotene.

Generally, the adverse effect of salinity on plant growth might be attributed to its retarding effect on cell division and cell elongation as well as interrupting the activity of meristimatic tissues, photosynthesis and translocation of assimilation products (Miller *et al.,* 1990). On the other hand, additional Ca^{2+} can ameliorate the depressive effect of salinity on the growth of plants (Zekri and Parsons, 1990).

Leaf mineral content:

Variations in leaf Cl, Na, Ca, Mg, N, P, K, Zn, Fe and Mn contents during both seasons due to specific and interaction effects of water types and supplemental Ca^{2+} are shown in Tables (4) and (5).

Leaf Cl and Na contents

As for the specific effect of salinity, data in Table (4) show that Cl and Na contents were significantly increased with increasing salinity. from 532 to 5120 mg L^{-1}. Cl and Na accumulation under increasing salinity were reported by El-Deeb (2002). In this concern, nutrient acquisition by plants can be disrupted by excessive ions in solution either via direct ionic competition between ions such as (Na^+ & K^+), (Ca^{2+} & Mg^{2+}) and (NO_3^- & Cl^-) or by the decrease in osmotic potential of solution reducing the mass flow of mineral nutrients to the root surface (Grattan and Grieve, 1992). This can be affected by absorption of ions from medium (Pasternak, 1987).

Concerning the specific effect of supplemental Ca^{2+}, data in Table (4) indicate that the addition of 4, 8 or 12 mM Ca^{2+} to irrigation water reduced Na and Cl concentrations in the leaves. This effect has been attributed to several actions of Ca^{2+}, including: 1) flocculation of the soil in which clay particles have been dispersed by Na, 2) preventing the uptake of the Na ion to injurious levels and allowing the uptake of K and 3) maintaining the selective permeability of membranes. Similar results were reported by Zekri and Parsons (1990) and Wright, *et al.,* (1995).

Referring to the interaction between salinity and supplemental Ca^{2+}, data in Table (5) reveal that all tested additional Ca^{2+} X high salinity caused a significant decrease in the uptake of Na and Cl as compared with the treated plants with 0 mM Ca^{2+} X highest salinity level. Similar findings were reported by Zekri and Parsons (1990) who demonstrated that $CaSO_4$ addition improves the ability of citrus seedlings to tolerate salt and the beneficial effect of adding Ca^{2+} to a saline irrigation water depended on the anion accompanying the Ca^{2+}.

Leaf Ca and Mg content

With respect to the specific effect of salt concentration in irrigation water, it is clear from the obtained results in Table (4) that Ca level in the leaves of "Manzanillo olive" plants was significantly increased with increasing salt concentration, while leaf Mg content took an opposite trend in this respect. These results confirmed the findings of El-Deeb (2000) and Garcil-Sanchez *et al.,* (2000).

Table (2): Specific effect of water salinity and calcium additions on some growth parameters of Manzanillo olive transplants (1997 and 1998 seasons)

	Stem length (cm)	Shoot Dw (g)	Root Dw (g)	Total plant Dw (g)	Shoot : root ratio	Chlorophyll (a) (mg kg^{-1} Fw)	Chlorophyll (b) (mg kg^{-1} Fw)	Carotene (mg kg^{-1} Fw)
				1997, season.				
Salinity				a- specific effect of salinity				
532 mgL^{-1} (Tap water)	73.3 a	19.5 a	17.4 a	36.7 a	1.10 b	3.8 a	1.8 a	5.6 a
3072 mgL^{-1} $(AW_1)^y$	55.1 b	14.7 b	11.8 b	26.6 b	1.24 a	2.5 b	1.0 b	3.8 b
5120 mgL^{-1} $(AW_2)^z$	46.9 c	11.5 c	10.3 c	21.9 c	1.10 b	2.4 b	1.0 b	3.4 c
Ca^{2+}				b- Specific effect of Ca^{2+} addition				
0 mM	54.2 d	13.5 d	11.5 c	25.0 d	1.17 a	2.6 c	1.2 b	3.7 d
4 mM	59.3 b	15.3 b	13.2 b	28.6 b	1.16 a	2.8 b	1.2 b	4.4 b
8 mM	63.4 a	17.7 a	15.2 a	32.9 a	1.16 a	3.5 a	1.4 a	5.0 a
12 mM	56.9 c	14.3 c	12.9 b	27.0 c	1.10 b	2.7 bc	1.2 b	3.9 c
				1998, season.				
Salinity				a- specific effect of salinity				
532 mgL^{-1} (Tap water)	68.2 a	17.3 a	14.1 a	31.4 a	1.23 b	3.6 a	2.0 a	5.8 a
3072 mgL^{-1} $(AW_1)^y$	46.5 b	11.9 b	8.7 b	20.6 b	1.36 a	2.8 b	1.3 b	4.6 b
5120 mgL^{-1} $(AW_2)^z$	36.7 c	9.7 c	7.8 c	17.4 c	1.23 b	2.4 c	1.2 b	3.7 c
Ca^{2+}				b- Specific effect of Ca^{2+} addition				
0 mM	45.3 d	10.9 c	9.1 d	20.0 c	1.20 c	2.6 c	1.3 b	3.7 d
4 mM	51.8 b	13.1 b	10.2 b	23.4 b	1.28 b	3.0 b	1.4 b	4.8 b
8 mM	56.6 a	14.9 a	11.8 a	26.6 a	1.28 b	3.3 a	2.0 a	5.4 a
12 mM	48.1 c	12.9 b	9.6 c	22.4 b	1.33 a	2.8 b	1.3 b	4.3 c

Means followed by the same letter(s) within each column are not significantly differed at 5 % level.

Y (AW_1) = Artesian well water from Abo Sakl, El-Arish, North Sinai Governorate.
Z (AW_2) = Artesian well water from El-Taweel, El-Arish,North Sinai Governorate.

Table (3): Effect of interaction between water salinity and Ca^{+2} additions on some growth parameters of Manzanillo olive transplants (1997 and 1998 seasons)

Interaction: Water salinity	Interaction: Ca^{2+} additions	Stem length (cm)	Shoot Dw (g)	Root Dw (g)	Total plant Dw (g)	Shoot: root ratio	Chlorophyll (a) (mg kg^{-1} Fw)	Chlorophyll (b) (mg kg^{-1}.Fw)	Carotien (mg kg^{-1} Fw)
					1997, season.				
532 mgL^{-1}	0 mM	70.9 c	17.2 d	14.8 c	31.7 d	1.15 d	3.6 b	1.7 b	4.7 d
	4 mM	74.2 b	19.4 b	17.4 b	36.9 b	1.11 e	3.8 b	1.8 ab	5.8 b
(tap water)	8 mM	78.1 a	23.1 a	20.5 a	43.6 a	1.12 e	1.4 a	2.0 a	6.8 a
	12 mM	69.9 c	18.4 c	16.8 c	34.6 c	1.05 g	3.7 b	1.7 b	5.1 c
3072 mgL^{-1}	0 mM	50.6 g	13.4 f	10.1 gh	23.6 fg	1.32 a	2.3 de	0.9 d	3.4 g
	4 mM	56.0 e	14.8 e	11.7 e	26.5 e	1.26 b	2.4 g	0.9 d	3.8 f
(AW1)	8 mM	61.3 d	17.0 d	13.9 d	30.9 d	1.21 c	3.2 c	1.2 c	4.3 e
	12 mM	52.7 f	13.6 f	11.7 e	25.3 ef	1.16 d	2.3 de	0.9 d	3.5 g
5120 mgL^{-1}	0 mM	41.1 I	10.1 h	9.5 h	19.7 I	1.05 g	2.1 e	0.9 d	3.1 h
	4 mM	47.8 h	11.8 g	10.6 fg	22.4 gh	1.11 e	2.4 d	0.9 d	3.6 g
(Aw2)	8 mM	50.7 g	13.0 f	11.2 ef	24.2 f	1.16 d	3.1 c	1.0 d	3.9 f
	12 mM	48.0 h	11.1 g	10.1 gh	21.3 hi	1.08 f	2.3 de	0.9 d	3.2 h
					1998, season.				
532 mgL^{-1}	0 mM	62.1 d	14.1 c	12.4 c	26.6 c	1.13 e	3.4 bc	1.9 a	4.6 d
	4 mM	70.8 b	17.5 b	13.8 b	31.3 b	1.26 d	3.6 b	2.0 a	5.7 b
(tap water)	8 mM	74.7 a	20.4 a	17.8 a	38.2 a	1.13 e	4.1 a	2.1 a	6.4 a
	12 mM	65.5 c	17.3 b	12.3 c	29.7 b	1.40 a	3.4 b	1.9 a	4.8 c
3072 mgL^{-1}	0 mM	41.4 g	10.9 f	8.0 f	18.6 efg	1.35 b	2.5 e	1.0 b	3.5 g
	4 mM	47.3 f	11.9 e	8.8 e	20.7 de	1.33 b	2.8 d	1.1 b	4.8 c
(AW1)	8 mM	53.6 e	13.2 d	9.3 d	22.2 d	1.41 a	3.2 c	2.0 a	5.5 b
	12 mM	43.5 g	11.5 ef	8.6 e	20.2 def	1.33 b	2.7 de	1.0 b	4.5 d
5120 mgL^{-1}	0 mM	32.3 i	7.8 h	6.9 g	14.8 h	1.12 e	2.1 g	0.9 b	3.1 h
	4 mM	37.3 h	10.1 g	8.0 f	18.1 fg	1.24 d	2.5 e	1.1 b	4.0 f
(Aw2)	8 mM	41.7 g	11.1 ef	8.4 e	19.2 efg	1.31 c	2.7 de	1.9 a	4.3 e
	12 mM	35.5 h	9.9 g	7.8 f	17.4 g	1.25 d	2.3 f	0.9 b	3.5 g

Means followed by the same letter(s) within each column are not significantly differed at 5 % level.

Y (AW_1) = Artesian well water from Abo Sakl, El-Arish, North Sinai Governorate.

Z (AW_2) = Artesian well water from El-Taweel, El-Arish, North Sinai Governorate.

Table (4): Specific effect of water salinity and calcium additions on leaf mineral content of Manzanillo olive transplants (1997 and 1998 seasons)

	Cl ($g\ kg^{-1}$)	Na ($g\ kg^{-1}$)	Ca ($g\ kg^{-1}$)	Mg ($g\ kg^{-1}$)	N ($g\ kg^{-1}$)	P ($g\ kg^{-1}$)	K ($g\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)
					1997, season.					
Salinity					a- specific effect of salinity					
532 mgL^{-1} (Tap water)	3.4 c	2.0 c	8.4 c	2.8 a	23.5 a	1.7 a	7.7 a	54 a	93 c	32 a
3072 mgL^{-1} $(AW_1)^y$	7.2 b	6.1 b	11.8 b	2.0 b	16.0 b	1.0 b	4.7 b	33 b	145 b	27 b
5120 mgL^{-1} $(AW_2)^z$	9.9 a	10.4 a	15.7 a	1.7 c	11.2 c	1.0 b	3.1 c	29 c	192 a	22 c
Ca^{2+}					b- Specific effect of Ca2+ addition					
0 mM	9.4 a	7.9 a	10.5 d	2.2 a	15.2 c	1.3 a	6.0 a	42 a	160 a	31 a
4 mM	7.3 b	6.7 b	11.5 c	2.2 a	16.7 b	1.2 ab	5.4 ab	40 b	148 b	28 b
8 mM	5.5 c	5.4 c	12.6 b	2.2 a	19.0 a	1.2 ab	5.0 bc	37 c	136 c	26 c
12 mM	5.0 d	4.7 d	13.1 a	2.1 a	16.8 b	1.1 b	4.4 c	36 d	128 d	24 d
					1998, season.					
Salinity					a- specific effect of salinity					
532 mgL^{-1} (Tap water)	3.0 c	2.0 c	9.1 c	3.1 a	19.4 a	1.4 a	6.8 a	59 a	85 c	30 a
3072 mgL^{-1} $(AW_1)^y$	6.2 b	5.9 b	2.1 b	2.3 b	13.2 b	1.0 b	4.2 b	38 b	141 b	26 b
510 mgL^{-1} $(AW_2)^z$	9.7 a	9.8 a	15.7 a	1.9 c	10.8 c	0.9 b	3.0 c	31 c	176 a	22 c
Ca^{2+}					b- Specific effect of Ca2+ addition					
0 mM	8.8 a	7.6 a	10.8 d	2.6 a	13.5 b	1.2 a	5.3 a	46 a	150 a	30 a
4 mM	6.8 b	6.3 b	12.1 c	2.5 ab	14.3 b	1.2 a	5.1 a	44 b	139 b	26 b
8 mM	5.0 c	5.3 c	12.9 b	2.4 bc	16.3 a	1.1 a	4.5 ab	42 c	130 c	24 c
12 mM	4.7 d	4.4 d	13.3 a	2.3 c	13.7 b	1.1 a	3.8 b	39 d	116 d	23 c

Means followed by the same letter(s) within each column are not significantly differed at 5 % level.

Y (AW_1) = Artesian well water from Abo Sakl, El-Arish, North Sinai Governorate.

Z (AW_2) = Artesian well water from El-Taweel, El-Arish, North Sinai Governorate.

Table (5): Effect of interaction between water salinity and Ca^{+2} additions on leaf mineral content of Manzanillo olive transplants (1997 and 1998 seasons)

Water salinity	Ca^{2} additions	Cl (g kg^{-1})	Na (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
1997, season.											
532 mgL^{-1}	0 mM	5.1 h	3.4 i	7.2 k	2.9 a	21.3 c	1.8 a	8.6 a	60 a	100 i	37 a
	4 mM	3.8 i	1.9 i	8.0 i	2.7 a	23.0 bc	1.6 b	8.3 ab	55 b	95 i	31 b
(tap water)	8 mM	2.6 i	1.5 k	9.0 i	2.8 a	26.6 a	1.8 a	7.3 bc	50 c	90 k	30 bc
	12 mM	2.0 k	1.1 l	9.2 i	2.7 a	23.3 b	1.5 b	6.6 cd	49 d	87 l	29 cd
3072 mgL^{-1}	0 mM	9.1 c	8.0 e	10.6 h	2.0 b	14.0 f	1.1 c	5.6 de	35 e	160 e	29 cd
	4 mM	7.1 e	7.1 f	11.7 g	2.1 b	16.0 e	1.0 c	4.6 ef	34 e	150 f	28 de
(AW1)	8 mM	6.5 f	5.0 g	12.1 f	1.9 bc	18.0 d	0.9 c	4.3 f	33 f	140 g	26 f
	12 mM	6.0 g	4.1 h	12.7 e	2.0 b	16.3 de	1.0 c	4.3 f	32 f	130 h	24 g
	0 mM	14.1 a	12.1 a	13.7 d	1.8 cd	10.3 h	1.0 c	4.6 f	30 g	220 a	27 ef
5120 ppm	4 mM	11.0 b	11.0 b	14.8 c	1.7 d	11.3 gh	0.9 c	3.3 fg	29 gh	200 b	24 g
(Aw2)	8 mM	7.5 d	9.6 c	16.6 b	1.8 cd	12.3 fg	0.9 c	3.3 fg	28 h	180 c	20 h
	12 mM	7.0 e	9.1 d	17.6 a	1.6 d	11.0 gh	1.0 c	2.3 g	28 h	167 d	20 h
1998, season.											
532 mgL^{-1}	0 mM	4.7 i	2.9 i	8.0 l	3.4 a	18.3 b	1.7 a	7.6 a	65 a	96 a	34 a
	4 mM	3.4 i	2.5 l	9.1 k	3.2 ab	19.3 b	1.6 a	7.3 b	60 b	90 i	30 b
(tap water)	8 mM	2.1 k	1.6 k	9.5 i	3.1 bc	23.3 a	1.6 a	6.6 c	58 b	84 i	28 c
	12 mM	2.0 k	1.0 l	9.8 i	3.0 c	18.6 b	1.5 a	5.6 d	52 c	70 k	27 cd
3072 mgL^{-1}	0 mM	8.6 c	7.8 e	10.2 h	2.5 d	12.3 d	1.0 b	4.6 e	41 d	156 d	30 b
	4 mM	6.1 e	6.2 f	11.9 g	2.4 d	13.0 d	1.0 b	4.6 e	40 de	149 e	27 cd
(AW1)	8 mM	5.2 g	5.6 g	12.8 f	2.3 d	15.3 c	1.0 b	4.3 f	38 e	140 f	24 e
	12 mM	5.0 h	4.3 h	13.1 e	2.3 d	12.3 d	0.9 b	3.3 h	35 f	121 g	23 ef
5120 mgL^{-1}	0 mM	13.3 a	12.1 a	14.1 d	2.1 e	9.9 e	1.0 b	3.6 g	33 g	200 a	26 d
	4 mM	11.0 b	10.3 b	15.3 c	2.0 ef	10.6 e	0.9 b	3.3 h	32 g	180 b	22 f
(Aw2)	8 mM	9.7 d	8.6 c	16.5 b	1.9 ef	12.3 d	0.9 b	2.6 i	31 j	166 c	20 g
	12 mM	7.1 e	8.0 d	17.1 a	1.8 f	10.3 e	0.8 b	2.6 i	29 h	157 d	19 g

Means followed by the same letter(s) within each column are not significantly differed at 5 % level.

Y (AW_1) = Artesian well water from Abo Sakl, El-Arish, North Sinai Governorate.

Z (AW_2) = Artesian well water from El-Taweel, El-Arish, North Sinai Governorate.

Regarding the specific effect of Ca^{2+} addition in irrigation water, data in Table (4) show that in both seasons, the supplemental Ca^{2+} led to an increase in leaf Ca content particularly with 12 mM Ca^{2+} followed by 8 and 4 mM compared with 0 mM Ca^{2+} treatment. While there was no clear-cut trend between Ca^{2+} addition and seasons in leaf Mg content.

Similar results were reported by Läuchli (1990). Calcium levels within the cytoplasm must remain low to avoid competition with Mg and inadvertent activation or inactivation of enzyme systems (Marschner, 1986).

Concerning the interaction between salinity and Ca^{2+} addition, data in Table (5) appear that the addition of Ca^{2+} to irrigation water increased leaf Ca content of salinity-treated plants. The most positive effect was induced by the combination of highest salinity level X 12 mM Ca^{2+} addition. On the other hand, Mg uptake showed an opposite trend in this respect. Similar results have been reported on highbush blueberry (Wright *et al.*, 1992). The presence of Ca^{2+} is necessary to maintain the Ca^{2+} and Mg^{2+} status of developing leaves to prevent the harmful displacement of Ca^{2+} by Na^{+} from the cell membranes and intercellular pools (Läuchli, 1990; Wright *et al.*, 1992).

Leaf N, P and K contents

Concerning the specific effect of salinity, data in Table (4) show that leaf N and K contents were negatively affected by increasing salinity. The most depressive effect of salinity on leaf N, P and K content was observed with the highest salinity level with significant differences among the other tested treatments. Similar results were reported by El-Deeb (2000).

As for the specific effect of Ca^{2+} addition, data Table (4) appear that the supplemental 8 mM Ca^{2+} led to improve leaf N contents. The presence of Ca^{2+} is necessary to maintain K^{+}/Na^{+} selectivity (Mightingale, 1937).

As for the interaction effect of salinity concentration X Ca^{2+} addition, data in Table (5) show that the lowest leaf N, P and K contents were produced by the combination between the highest salinity concentration X 12 mM Ca^{2+} addition. This trend supported the findings of Maklad (2003).

Leaf Zn, Fe and Mn contents

Concerning the specific effect of salinity, data in Table (4) show that leaf Zn and Mn contents were decreased with increasing salinity, while leaf Fe content took an opposite trend in this respect. These results go in line with those reported by El-Deeb (2000). The inhibiting effect of salinity on uptake of some elements may be attributed to the reducing effect of salinity on the activity of xylem tissues which in turn reduces the absorption and translocation of such nutrients (Nijjar, 1985). Moreover, some iron may be absorbed by plants as a result of the intimate contact between the root surface and the soil particles (Meyer, *et al.*, 1960).

As for the specific effect of Ca^{2+} addition, data in Table (4) reveal that leaf Zn, Fe and Mn content were depressed significantly with increasing Ca^{2+} concentration in the irrigation water as compared with those of the control (0 mM Ca^{2+} addition). Similar results were reported by Maksoud and Haggag (2000). The effect of $CaSO_4$ on depressing the heavy metals accumulation in plant may be due, essentially, to increased availability of Ca independent of soil pH (Alva *et al.*, 1986), although the beneficial effect of increases in Ca availability as competitive element to adsorptive processes of heavy metals.

Referring to the interaction effect of salinity X Ca^{2+} addition on leaf Zn, Fe and Mn contents, data in Table (5) show that the lowest leaf Zn, Fe contents were produced by the combination between the highest salinity concentration X 12 mM Ca^{2+} addition.

In this concern, it is well known that Ca plays an important role for the integrity of the selective ion transport mechanism and also inhibits the absorption of heavy metals by plant roots (Maksoud and Haggag, 2000).

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تأثير ملوحة ماء الري وإضافة الكالسيوم على النمو والمحتوى المعدني لشتلات الزيتون المنزانيللو

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أجريت هذه الدراسة على شتلات الزيتون منزانيللو عمر سنة والمنزرعة في تربة طمييه رملية في أنابيب بلاستيك (٤٠سم طول ١٤ سم قطر) ورويت بمياه الآبار من بئرين بمنطقة العريش بشمال سيناء هما بئر أبو صقل حيث المحتوى الملحي ٢٠٧٢ جزء في المليون والنسبة الادمصاصية للصوديوم ٦.٨ وبئر الطويل وملوحته ٥١٢٠ جزء في المليون والنسبة الادمصاصية للصوديوم ٢.٦٣، مقارنة بمياه الصنبور وملوحتها ٥٣٢ جزء في المليون والنسبة الادمصاصية للصوديوم ٦.٢ مع إضافة أيون الكالسيوم (كبريتات الكالسيوم) مع مياه الري بالتركيزات التالية صفر، ٤، ٨، ١٢ ملليمول.

أوضحت النتائج أن ري شتلات الزيتون المنزانيللو بمياه الآبار العالية الملوحة)بئر الطويل - ٥١٢٠ جزء في المليون) أدى إلى نقص معنوي في طول الساق والوزن الجاف للمجموع الخضري والجذري وأيضا محتوى الورقة من كلوروفيل (أ، ب) والكاروتين. وكذلك تركيز النيتروجين والفسفور والبوتاسيوم والماغنسيوم والزنك والمنجنيز فى الأوراق عن مثيلتها التي تروى بماء الصنبور (٥٣٢ جزء في المليون).

كذلك أظهرت النتائج أن إضافة كبريتات الكالسيوم إلى مياه الري العالية الملوحة قد قلل من التأثير الضار للملوحة على النمو الخضري وزاد من محتوى الورقة من عناصر النيتروجين والفسفور والبوتاسيوم والماغنسيوم والزنك والمنجنيز كما وقلل من محتوى الورقة من عنصري الكلور والصوديوم.

وبناء على ما سبق فإنه تحت ظروف الري بهذه النوعية من المياه (العالية الملوحة والصودية) يمكن التوصية بإضافة أيون الكالسيوم (كبريتات الكالسيوم) بتركيز ٨ ملليمول إلى تلك المياه لرى شتلات الزيتون المنزانيللو وذلك لتجنب الآثار الضارة للملوحة والصودية وتحسين نمو الشتلات.