Role of rootstock and scion on root and leaf ion accumulation in lemon trees grown under saline conditions

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Abstract — **Introduction**. In southeastern Spain, irrigation water usually contains high concentrations of Cl^- and Na^+. The purpose of the present study was to compare, under these saline conditions, the behaviour of three ungrafted rootstocks, sour orange, *Citrus macrophylla* and *C. volkameriana*, as well as that of three lemon scions grafted on those same rootstocks. **Materials and methods**. The incidence of the rootstock and the scion on the accumulation of different ions was studied in several scion/rootstock conbinations. In the treated plants, the irrigation water contained 50 mmol of NaCl. Concentrations of K, Cl, Na, N, P, Ca and Mg ions were analyzed in the leaves as well as in the fibrous roots. **Results**. Differences in growth of the plants were evident: in all cases, *C. macrophylla* was the less affected rootstock. **Discussion**. The obtained concentrations for Cl^- and Na^+ in the fibrous roots and leaves indicate that none of the used rootstocks was able to exclude these ions from the leaves. In general, the final concentrations for these two ions depended on the different scion/rootstock combinations. Macro- and micronutrient concentrations were more or less affected by these combinations; nevertheless, in almost all cases, the treated plants grafted on *C. macrophylla* contained more N, Fe and Mn and had a better growth than on the two other rootstocks. **Conclusion**. The obtained results showed that the combination of Fino on *C. macrophylla* is quite adequate for growth in moderatly saline conditions. (© Elsevier, Paris.)

Spain / *Citrus* / salt tolerance / rootstock scion relationships / chemical composition / leaves / roots

Influence du porte-greffe et du greffon sur l'accumulation d'ions dans les racines et les feuilles de citronniers cultivés sur sols salins.

Résumé — **Introduction**. Dans le sud de l'Espagne, l'eau d'irrigation est, en général, riche en ions Cl^- and Na^+. L'étude a cherché à comparer les comportements, sur sols salins, de trois porte-greffes non greffés – orange amère, *Citrus macrophylla* et *C. volkameriana* – et de trois variétés de citronniers greffés sur ces mêmes porte-greffes. **Matériel et méthodes**. L'effet du porte-greffe et du greffon sur l'accumulation de différents ions a été étudié sur diverses combinaisons porte-greffe–greffon. Les plants traités ont été irrigués avec de l'eau contenant 50 mmol de chlorure de sodium (NaCl). Les concentrations en ions K, Cl, Na, N, P, Ca et Mg des feuilles et des racines de ces plants ont été ensuite mesurées. **Résultats**. L'étude a mis en évidence des différences de croissance entre plants ; dans tous les cas, *C. macrophylla* a été le porte-greffe le moins affecté par la salinité. **Discussion**. Aucun des porte-greffes utilisés n'a été capable d'empêcher l'accumulation de Cl^- et de Na^+ dans les feuilles, dont la concentration finale a dépendu, le plus souvent, de la combinaison porte-greffe–greffon considérée. Les teneurs en macro et microéléments ont été plus ou moins affectées par ces combinaisons ; néanmoins, dans presque tous les cas, les plants traités, greffés sur *C. macrophylla,* ont accumulé davantage de N, Fe et Mn et ont présenté une meilleure croissance que ceux greffés sur les deux autres porte-greffes testés. **Conclusion**. Les résultats obtenus ont montré que la combinaison « *C. macrophylla*–variété Fino » pouvait être conseillée sur des sols présentant une salinité modérée. (© Elsevier, Paris.)

Espagne / *Citrus* / tolérance au sel / relation greffon-porte-greffe / composition chimique / feuille / racine

1. introduction

Lemon and orange trees are widely cultivated in southeastern Spain where the predominant climate conditions are those typical of a semiarid zone. This make citrus plantings irrigation- dependent. In this area of Spain, the irrigation water is usually of poor quality, containing high concentrations of Cl^- and Na^+ [1].

Citrus response to salinity has been recently reviewed by Maas [2]. The effect of salinity on citrus is generally related with the partial ability of the rootstock to exclude Cl^- and/or Na^+ into the leaves [3–6]) and with the capacity of the scion itself to restrict the accumulation of those ions in some scion-rootstock combinations [7–10]). For a given rootstock, lemons have been reported as more salt-sensitive than orange scions [7]. The effects of salinity on citrus fruit production [11–15], Cl^- and Na^+ uptake, water relations and gas exchange [7–9, 16, 17] are well documented. However, there is little information on rootstock-lemon combinations in terms of the nutritional imbalance of macro- and micronutrients. The little available data in this respect have been obtained from experiments with rootstock seedlings [18, 19].

The purpose of the present study was to compare, under NaCl saline conditions, the behaviour of three ungrafted rootstocks as well as that of three lemon scions grafted on those same rootstocks. The comparison was carried out in relation to the total growth, as well as the accumulation of Cl^-, Na^+ and K^+ in roots and leaves. In addition to this, the nutritional imbalance of macro- and micronutrients in both roots and leaves was also investigated.

2. materials and methods

2.1. growth of plants

One-year-old uniform seedlings of sour orange (*Citrus aurantium* L.), *Citrus macrophylla* Wester and *Citrus volkameriana* Ten. & Pasq. were grown together to selected clones of half-year-old Fino, Verna and Eureka lemon trees (*Citrus limon* (L.) Burm. f.), each one budded on one-year-old seedlings of the mentioned rootstocks. The twelve resultant combinations were grown in 3 L plastic containers filled with siliceous sand. The rootstocks seedlings were from a commercial nursery and were grafted in the glasshouse with virus free buds of the lemon scions.

Four replications, each consisting of four plants of the 12 budded or unbudded combinations, were used for the study. The plants were three times per week irrigated generously, in order to ensure the flow of water through the pots and to avoid excessive accumulation of salt in the growing medium. The nutrient solution had the following composition (mmol): 3 KNO_3; 4 Ca $(NO_3)_2 \cdot 4H_2O$; 2 H_3PO_4; 1 $MgSO_4 \cdot 7H_2O$; with (mmol): 21.9 $MnSO_4H_2O$; 6.4 Fe-EDTA; 64.7 H_3BO_3; 2.7 $ZnSO_4 \cdot 7H_2O$; 2.5 $CuSO_4 \cdot 5H_2O$ and 0.6 MoO_3, pH 5.8. NaCl was added to attain the final concentration of 50 mmol. The plants were grown for 6 months under differential salinization in a glasshouse with partially controlled conditions. The temperature was maintained between 13 and 32 °C and the relative humidity was always kept over 65%. Before salinization, the budded plants were cut 0.25 m above the bud union.

2.2. ion analysis

At the end of the experiment, the seedlings were removed from their pots. The roots were washed with tap water to separate the sand and rinsed with deionized water. Fibrous roots and leaves were separated from the shoots, oven-dried for 48 h at 65 °C, weighted, ground to a fine powder able to pass through a 0.5 mm mesh, and stored for mineral analysis. Total nitrogen was determined by the micro-Kjeldahl method. Chloride content was extracted with a 0.1 N solution of nitric acid and 10%

Table I.
Dry weight (g) of control (c) and treated (t) with 50 mmol of NaCl plants for different lemon-rootstock combinations.

Rootstock		Unbudded	Scions		
			Fino	Verna	Eureka
Citrus volkameriana	c	142.8 ± 14.0	68.2 ± 3.7	47.4 ± 8.0	69.6 ± 7.5
	t	67.2 ± 6.2	66.8 ± 3.0	49.7 ± 11.0	45.1 ± 6.3
Citrus macrophylla	c	113.3 ± 12.9	74.9 ± 3.3	58.6 ± 7.7	56.0 ± 6.8
	t	106.2 ± 14.7	71.9 ± 6.4	51.5 ± 4.3	61.3 ± 11.1
Sour orange	c	107.1 ± 7.5	73.5 ± 8.2	54.0 ± 7.9	70.4 ± 9.5
	t	84.7 ± 14.9	51.3 ± 7.8	27.6 ± 3.2	29.8 ± 5.5

acetic acid and determined according to the method of Guilliam [20]. The remaining elements were measured by atomic absorption spectrophotometry in the dilute nitric-perchloric (2:1) acid digests, except phosphorus which was colorimetrically determined by using the molybdenum blue method described by Dickmann and Bray [21].

3. results

The final dry weight for the different combinations in control and treated plants is shown in *table I*. In all cases the unbudded rootstocks had a reduced growth in the treated plants. The highest decrease of growth occurred in *Citrus volkameriana*. Significant reduction of growth was also noted for most of the lemon/rootstock combinations. There was a rootstock-scion interaction. The most affected organs were the leaves and the fibrous roots. The main reduction was observed in the combination of Eureka lemon on sour orange rootstock, with a dry weight of 70.4 g in the control and only 29.8 g in the treated plants.

Plants of the unbudded rootstocks and of all combinations showed differences in Cl^-, Na^+ and K^+ concentrations in both treated and control plants (*figures 1,2, 3*). Cl^- and Na^+ increased in the treated plants, while K^+ decrea-

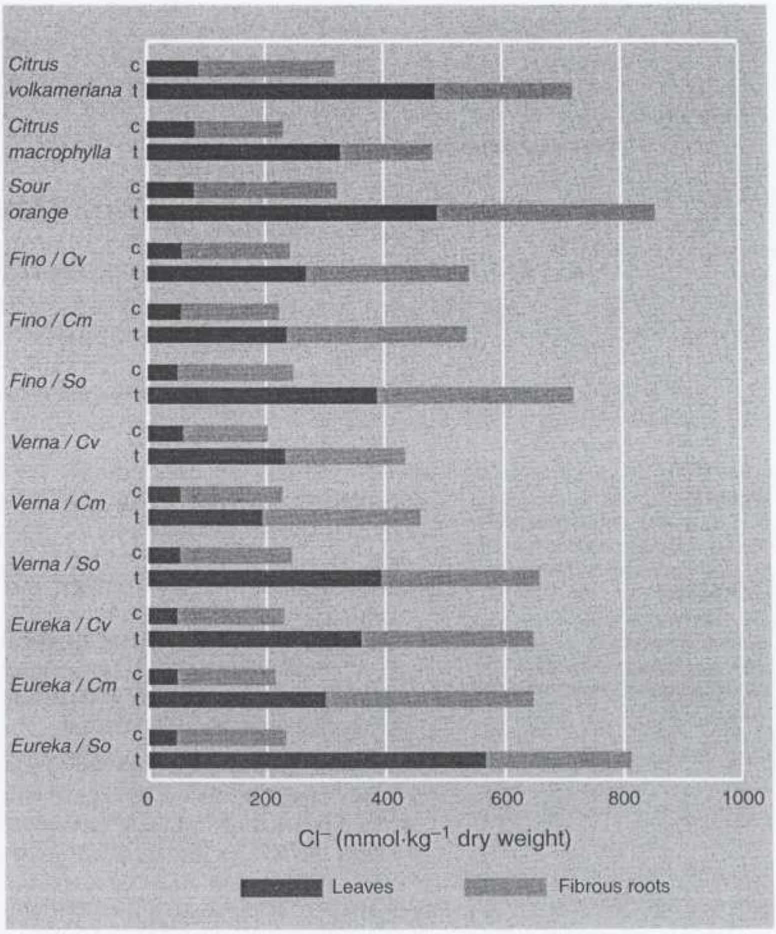

Figure 1.
Cl^- concentration in leaves and in fibrous roots of unbudded rootstocks and different lemon/rootstock combinations. *Cv* = *C. volkameriana*; *Cm* = *C. macrophylla*; *So* = sour orange; c = control; t = treated with 50 mmol of NaCl.

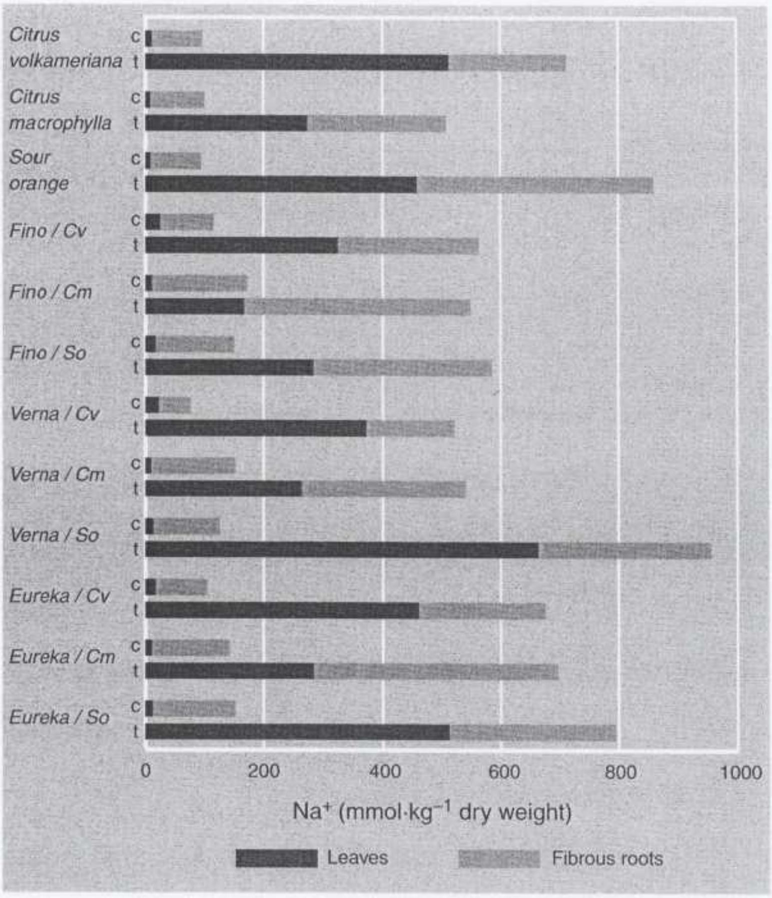

Figure 2.
Na^+ concentration in leaves and in fibrous roots of unbudded rootstocks and different lemon/rootstock combinations.
Cv = *C. volkameriana*;
Cm = *C. macrophylla*;
So = sour orange; c = control;
t = treated with 50 mmol of NaCl.

sed except for some of the combinations on *Citrus macrophylla*. The larger increase of Cl^- and Na^+ occurred in the combinations on sour orange and mostly corresponded to increments in the leaf content of these ions. In general, *C. volkameriana* and *C. macrophylla* behaved rather similarly while sour orange was the most affected.

For the two ions Cl^- and Na^+, most of the content in the control plants was in the fibrous roots, while K^+ was more or less shared by leaves and fibrous roots.

Nitrogen content (*table II*) showed almost no variation in treated plants as compared to the controls. About the same concentrations were detected in leaves and in fibrous roots.

Phosphorous (*table III*) also varied little in the treated plants. Its content was always higher in fibrous roots than in leaves.

With respect to calcium and magnesium (*tables IV, V*), there was a clear decrease of their leaf content for both ions in all combinations, while, in the case of fibrous roots, only the concentration of magnesium decreased while that of calcium was either maintained or increased.

Leaves and fibrous root contents of Fe, Mn and Zn are shown in *table VI*. In all cases, the amount of these ions in the leaves was very low and had only very small variations with slight reduction for some of the combinations. The content in fibrous roots was higher and did not show a clear tendency in the treated plants, although in some cases a marked decrease occurred.

4. discussion

The analysis of the results shows that the addition of NaCl to the nutrient solution induced differences in the reduction of growth in budded vs. unbudded plants. The decrease in total dry weight for the unbudded rootstocks in response to salinity was highest in *Citrus volkameriana* and lowest in *Citrus macrophylla* (*table I*). In budded plants, Verna had the lowest growth in any of the rootstocks. Also an incidence of the scion/rootstock combination, mostly in the salt treated plants, was evident (*table I*). There was not a clear correlation between unbudded rootstocks and budded plants on the same rootstocks when the growth in both cases was compared, i.e. the reduction of growth of the scion depended on the rootstock. Fino lemon had less growth in treated plants on sour orange than on *C. volkameriana*, although the last rootstock had less growth than sour orange when unbudded. This fact indicates that a factor of compatibility should be considered with respect to the growth of the plants.

In the treated plants there was a clear relation between accumulation of Cl^- and Na^+ and their growth. This suggests the possibility of either a toxicity effect of these ions or the physiological hindrances that they can cause when accumulated by the effect of salinity. García-Legaz et al. [17], studying the same combinations, found that the assimilation rate of CO_2 and the stomatal conductance in leaves were highly reduced by salinity.

The results obtained in this study are in contradiction with those reported by Nieves et al. [10]. These authors observed in a study under hydroponic conditions, that Fino and Verna lemons had a better growth budded on sour orange than on *C. macrophylla*. The explanation to this could be the high sensitivity of the last rootstock to flooding conditions.

The obtained concentration for Cl^- and Na^+ in the fibrous roots and in the leaves indicate that none of the used rootstocks was able to exclude these ions from the leaves (*figures 1, 2*). Under saline conditions, it seems that the root system of *C. macrophylla* has a higher capacity to retain Cl^- and Na^+ than that of the two other rootstocks. This fact retards and reduces the final concentrations of these ions in the

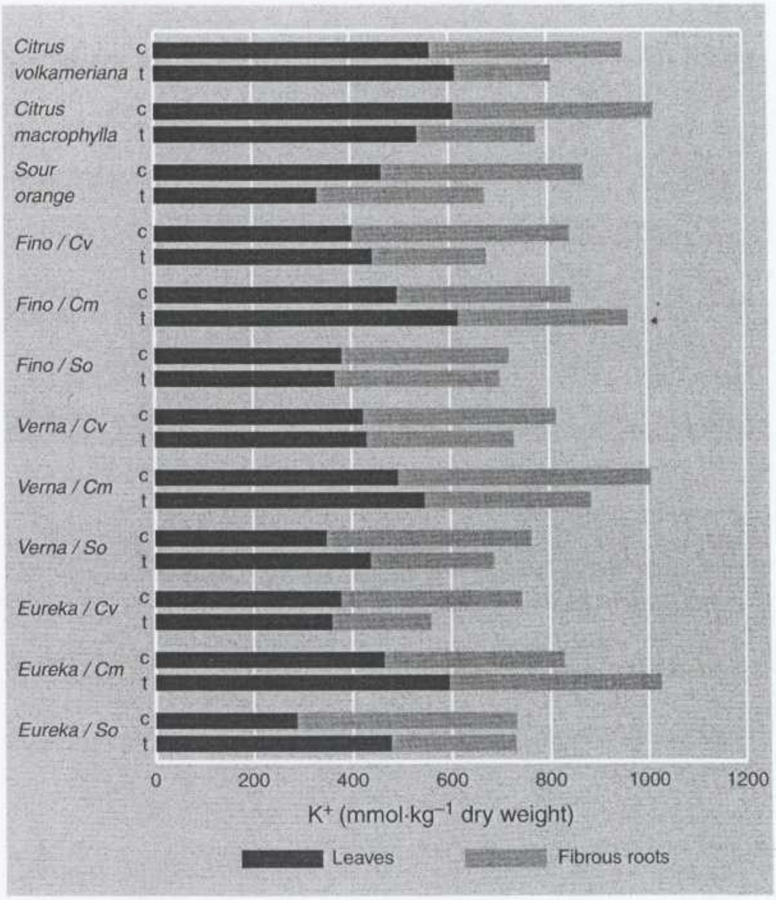

Figure 3.
K^+ concentration in leaves and in fibrous roots of unbudded rootstocks and different lemon/rootstock combinations. *Cv* = *C. volkameriana*; *Cm* = *C. macrophylla*; *So* = sour orange; c = control; t = treated with 50 mmol of NaCl.

Table II.
Nitrogen content ($mmol \cdot kg^{-1}$ dry weight) in fibrous roots and leaves of different lemon/rootstock combinations; c = control; t = treated (50 mmol of NaCl).

Rootstock		Fino		Verna		Eureka	
		Fibrous roots	Leaves	Fibrous roots	Leaves	Fibrous roots	Leaves
Citrus volkameriana	c	1 925 ± 85	1 775 ± 63	1 875 ± 25	1 875 ± 48	1 875 ± 95	1 875 ± 48
	t	1 200 ± 71	1 900 ± 58	1 725 ± 103	1 900 ± 71	1 625 ± 95	1 950 ± 104
Citrus macrophylla	c	1 725 ± 48	2 175 ± 85	1 725 ± 48	2 175 ± 111	2 025 ± 48	2 150 ± 50
	t	1 950 ± 29	2 075 ± 48	1 750 ± 65	2 150 ± 104	1 975 ± 63	2 075 ± 48
Sour orange	c	1 625 ± 63	1 750 ± 96	1 700 ± 71	1 700 ± 91	1 725 ± 25	1 700 ± 41
	t	1 675 ± 95	1 800 ± 71	1 600 ± 92	1 633 ± 47	1 700 ± 41	1 667 ± 62

Table III.
Phosphorus content (mmol·kg^{-1} dry weight) in fibrous roots and leaves of different lemon/rootstock combinations; c = control; t = treated (50 mmol of NaCl).

Rootstock		Fino		Verna		Eureka	
		Fibrous roots	Leaves	Fibrous roots	Leaves	Fibrous roots	Leaves
Citrus volkameriana	c	94 ± 8	47 ± 5	104 ± 3	52 ± 1	110 ± 3	54 ± 2
	t	92 ± 7	62 ± 3	107 ± 5	54 ± 2	102 ± 14	66 ± 6
Citrus macrophylla	c	111 ± 6	57 ± 4	108 ± 9	62 ± 3	92 ± 2	57 ± 4
	t	104 ± 8	58 ± 3	99 ± 4	57 ± 2	71 ± 3	56 ± 2
Sour orange	c	102 ± 8	48 ± 4	81 ± 7	50 ± 3	77 ± 5	53 ± 3
	t	84 ± 3	58 ± 7	102 ± 9	56 ± 4	82 ± 5	56 ± 8

Table IV.
Calcium content (mmol·kg^{-1} dry weight) in fibrous roots and leaves of different lemon/rootstock combinations; c = control; t = treated (50 mmol of NaCl).

Rootstock		Fino		Verna		Eureka	
		Fibrous roots	Leaves	Fibrous roots	Leaves	Fibrous roots	Leaves
Citrus volkameriana	c	761 ± 52	304 ± 34	797 ± 75	372 ± 22	859 ± 15	869 ± 21
	t	971 ± 75	215 ± 23	1 088 ± 5	197 ± 10	935 ± 10	2 209 ± 4
Citrus macrophylla	c	876 ± 27	424 ± 19	926 ± 52	409 ± 44	820 ± 22	484 ± 14
	t	941 ± 69	316 ± 16	918 ± 28	297 ± 26	820 ± 63	333 ± 18
Sour orange	c	1 049 ± 8	403 ± 33	1 091 ± 15	492 ± 31	921 ± 70	441 ± 24
	t	1 051 ± 36	330 ± 16	1 148 ± 32	242 ± 12	1 008 ± 41	325 ± 101

Table V.
Magnesium content (mmol·kg^{-1} dry weight) in fibrous roots and leaves of different lemon/rootstock combinations; c = control; t = treated (50 mmol of NaCl).

Rootstock		Fino		Verna		Eureka	
		Fibrous roots	Leaves	Fibrous roots	Leaves	Fibrous roots	Leaves
Citrus volkameriana	c	106 ± 6	112 ± 12	95 ± 4	102 ± 4	100 ± 7	104 ± 4
	t	56 ± 6	58 ± 2	67 ± 6	52 ± 4	52 ± 5	63 ± 5
Citrus macrophylla	c	143 ± 10	108 ± 2	151 ± 32	100 ± 8	116 ± 14	100 ± 6
	t	60 ± 3	78 ± 2	69 ± 2	68 ± 2	59 ± 4	71 ± 3
Sour orange	c	93 ± 10	140 ± 7	90 ± 5	140 ± 9	120 ± 13	141 ± 11
	t	52 ± 2	80 ± 10	76 ± 3	68 ± 9	60 ± 5	84 ± 9

Table VI.
Iron, zinc and manganese contents (mmol·kg^{-1} dry weight) in fibrous roots and leaves of different lemon/rootstock combinations; c = control; t = treated (50 mmol of NaCl).

Ion analysed	Rootstock		Fino		Verna		Eureka	
			Fibrous roots	Leaves	Fibrous roots	Leaves	Fibrous roots	Leaves
Iron	*Citrus volkameriana*	c	20.6 ± 2.4	2.06 ± 0.43	19.3 ± 1.0	1.62 ± 0.11	23.6 ± 1.4	2.06 ± 0.10
		t	22.9 ± 2.5	1.46 ± 0.03	23.9 ± 2.5	1.06 ± 0.08	23.9 ± 2.6	1.22 ± 0.04
	Citrus macrophylla	c	30.1 ± 3.2	2.13 ± 0.19	25.0 ± 1.5	2.08 ± 0.26	22.4 ± 1.2	2.40 ± 0.03
		t	29.5 ± 4.0	1.79 ± 0.20	33.7 ± 0.9	1.67 ± 0.19	28.8 ± 5.2	1.65 ± 0.17
	Sour orange	c	34.7 ± 2.0	1.68 ± 0.21	20.4 ± 0.7	1.53 ± 0.07	29.0 ± 1.2	1.77 ± 0.15
		t	22.4 ± 3.1	1.06 ± 0.17	19.0 ± 2.0	0.63 ± 0.08	29.3 ± 1.6	1.04 ± 0.12
Zinc	*Citrus volkameriana*	c	2.52 ± 0.08	0.29 ± 0.05	1.68 ± 0.14	0.20 ± 0.12	2.41 ± 0.52	0.22 ± 0.01
		t	1.91 ± 0.21	0.21 ± 0.01	2.23 ± 0.08	0.21 ± 0.02	2.11 ± 0.22	0.20 ± 0.02
	Citrus macrophylla	c	4.51 ± 0.92	0.37 ± 0.04	4.27 ± 1.00	0.27 ± 0.03	2.15 ± 0.17	0.32 ± 0.01
		t	2.04 ± 0.16	0.26 ± 0.02	2.80 ± 0.45	0.28 ± 0.02	1.69 ± 0.17	0.28 ± 0.01
	Sour orange	c	3.13 ± 0.61	0.20 ± 0.01	2.71 ± 0.64	0.21 ± 0.02	2.51 ± 0.47	0.21 ± 0.01
		t	1.62 ± 0.15	0.17 ± 0.01	1.86 ± 0.25	0.16 ± 0.02	3.26 ± 0.42	0.33 ± 0.03
Manganese	*Citrus volkameriana*	c	13.4 ± 1.7	0.48 ± 0.01	12.0 ± 1.6	0.42 ± 0.04	14.4 ± 1.3	0.43 ± 0.02
		t	14.5 ± 1.4	0.45 ± 0.06	14.7 ± 1.7	0.40 ± 0.03	13.0 ± 0.5	0.48 ± 0.04
	Citrus macrophylla	c	21.0 ± 1.5	0.66 ± 0.05	19.0 ± 4.1	0.70 ± 0.06	17.3 ± 2.1	0.77 ± 0.03
		t	15.7 ± 1.1	0.66 ± 0.04	13.8 ± 1.1	0.64 ± 0.08	12.0 ± 1.0	0.77 ± 0.04
	Sour orange	c	14.2 ± 1.3	0.51 ± 0.02	15.2 ± 1.0	0.69 ± 0.05	17.2 ± 1.3	1.55 ± 0.04
		t	11.7 ± 1.0	0.44 ± 0.04	12.6 ± 0.7	0.41 ± 0.04	11.4 ± 0.6	0.55 ± 0.09

leaves. In general, the final concentrations for these two ions depended on the different combinations (*figures 1, 2*).

A marked effect of the rootstock on the Cl^- and Na^+ concentrations was evident in all cases. Sour orange was always the rootstock that induced the highest accumulation of these ions. Also, the effect of the scion was clear in all cases. On any of the rootstocks, Fino and Verna behaved similarly while Eureka had a higher concentration of Cl^- and Na^+. Similar results were obtained in Navel oranges and Clementines on Cleopatra mandarin and on Troyer citrange [9]. Nevertheless, the results do not agree with those of Behboudian et al. [22] who indicated that the accumulation of Cl^- was controlled by the rootstock and that of Na^+ by the scion.

An adverse effect has been attributed to the K^+ deficiency [23]. In this study, the salinity maintained or increased the K^+ leaf concentrations in all combinations, although it was reduced in the rootstock for all three scions on *C. volkameriana* and on sour orange. This may be due to the direct effect of Na^+, that displaces K^+, or to a loss of K^+ from the root tissues. This agrees with the observations of Walker and Douglas [24] and Zekri and Parsons [19] in different citrus rootstocks.

Macro- and micronutrient concentrations in the studied combinations were more or less affected by the combination. There was a marked effect of salinity on the reduction of Ca and Mg concentrations in leaves in all cases. Nevertheless, the concentrations of Ca and Fe in the fibrous roots were barely affected by salinity. This indicates that the translocation of these ions from roots to leaves is controlled by the salinity. Zid and Grignon [25] demonstrated that the translocation of Na^+ to the leaves in *C. aurantium* lead to a displacement of the apoplasmic Ca.

The obtained results also showed that, in almost all cases, the treated plants on *C. macrophylla* contained more N, Fe and Mn and had a better growth than on the two other rootstocks.

5. conclusion

The present work shows that the most commonly used rootstocks for lemons have, in general, a low ability to exclude Cl^- and Na^+. The final accumulation of these ions in the leaves of the scion depends on the scion/rootstock combination. There are other factors such as the climate, soil, aeration, Ca^{2+} concentration in the soil, etc. that are also influencing the final results. In order to decide the most adequated rootstock to use in a given situation, all these factors should be considered, as well as the good scion/rootstock compatibility. The obtained results indicate that Fino lemon on *C. macrophylla* is a good combination for places with moderatly saline conditions.

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Influencia del portainjerto y del injerto de púa en la acumulación de iones en las raíces y hojas de los limoneros cultivados en suelos salinos.

Resumen — Introducción. En el sur de España el agua de regadío es, en general, rica en iones Cl^- y Na^+. El objetivo del estudio es comparar los comportamientos, en suelo salino, de tres portainjertos no injertados - naranja amarga, *Citrus macrophylla* y *C. volkameriana* - y de tres variedades de limoneros injertados en esos mismos portainjertos. **Material y métodos**. El efecto del portainjerto y del injerto de púa en la acumulación de diferentes iones se estudió en diferentes combinaciones portainjerto/injerto. Las plantas tratadas se regaron con agua que contenía 50 mmol de cloruro de sodio (NaCl). Luego se midieron las concentraciones de iones de K, Cl, Na, N, P, Ca y Mg en las hojas y en las raíces de estas plantas. **Resultados**. El estudio evidenció una serie de diferencias en el crecimiento de las plantas; en todos los casos, *C. macrophylla* fue el portainjertos menos afectado por la salinidad. **Discusión**. Ninguno de los portainjertos empleados fue capaz de impedir la acumulación de Cl^- y Na^+ en las hojas, cuya concentración final dependió a menudo de la combinación portainjerto/injerto considerada. Los contenidos en macro y microelementos se vieron más o menos afectados por estas combinaciones; no obstante, en casi todos los casos, las plantas tratadas, injertadas en *C. macrophylla*, acumularon más N, Fe y Mn y presentaron un mejor crecimiento que aquellas que se injertaron el los otros dos portainjertos probados. **Conclusión.** Los resultados obtenidos muestran que la combinación "*C. macrophylla*/ variedad Fino" puede aconsejarse en los suelos con salinidad moderada. (© Elsevier, Paris.)

España / *Citrus* / tolerancia a la sal / relaciónes patrón injerto / composición química / hojas / raíces