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FIRST-YEAR RESPONSE OF 'RUBY RED' GRAPEFRUIT ON FOUR ROOTSTOCKS TO FERTILIZATION AND SALINITY

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Abstract. **Young 'Ruby Red' grapefruit trees on sour orange (SO), Carrizo citrange (CA), Cleopatra mandarin (CL), or Swingle citrumelo (SW) rootstocks were used in a randomized split plot field experiment with 4 replications. Irrigation water had electrical conductivities of 0.7, 2.3, 3.9, or 5.5 dS m^{-1} (500, 1600, 2700, or 3800 ppm TDS). Three fertilizer applications included: fertigating weekly with first-year totals of 0.34 lb N tree^{-1} (L-34) or 0.23 lb N tree^{-1} (L-23), and broadcasting granular fertilizer at 6-week intervals with a total application of 0.54 lb N tree^{-1} yr^{-1} (D-54). Tree measurements taken in June and December showed reductions in canopy volumes of about 7% for each 1.0 dS m^{-1} increase in irrigation water salinity level above the base level of 0.7 dS m^{-1} (about 10% reduction for each 1000 ppm above 500). Trees on all rootstocks had either excessive leaf Na or Cl accumulations at the highest salinity levels. Trees on CL were able to exclude Cl better than the other rootstocks. Trees on Carrizo accumulated high levels of Cl, but they were the most effective at excluding Na. Trees on CL had the greatest growth and those on SO had the least. Growth of trees on SW was slightly more than trees on CA, but both grew about 15-20% less than trees on CL. The L-34 fertigation proved superior to the other fertilization methods for all growth measurements. Growth was greater for the L-34 treatments even though the total seasonal N application rate was only about 60% of the broadcast fertilizer (D-54) rate. This advantage was apparent in all rootstocks at all salinity levels.**

Flatwoods citrus growers often have only poor quality (high salinity) water available for irrigation. As early as 1900, damage to citrus trees on Florida's east coast was attributed to the high mineral content of artesian well water (Robinson, 1900). Wander and Reitz (1951) analyzed water samples from 160 east coast Flatwoods irrigation wells and found that most of them had high salinity levels, with an average of 2054 ppm total dissolved solids (TDS) per well. Many Flatwoods growers have no alternative other than to use this poor quality water for citrus irrigation. Therefore, knowing how to minimize the effects of saline irrigation water on citrus is an important production consideration.

Although citrus is known to be a salt sensitive crop, many of the common citrus rootstocks differ in their tolerance to salinity (Bernstein, 1969; Cooper et al., 1952; Wutscher, 1979). Field studies in Texas (Chapman, 1968; Cooper, 1961) and California (Newcomb, 1978) tested salinity tolerance of rootstocks according to their ability to exclude Cl from leaves. In general, the decreasing order of salinity tolerance has been found to be: Cleopatra mandarin > Sour orange > Sweet orange = Swingle citrumelo > Rough lemon > *Poncirus trifoliata*. Differences have also been shown in salt tolerance of citrus scions. Grapefruit and lemon trees tend to be less salt tolerant than orange varieties (Cooper et al., 1952; Levy and Shalhevet, 1985).

Recently, widespread interest in salinity has increased along with the rapid adoption of microirrigation systems. These systems allow nutrient salts to be routinely added to the irrigation water (fertigation) and to be applied over a limited ground surface area. However, fertigation can easily add 1000 ppm or more of salts to the irrigation water when fertigations take place. Therefore, concerns about the best way to manage microirrigation systems have increased among growers using poor quality irrigation water.

Summer rains in Florida quickly reduce soil salinity by leaching accumulated salts from the tree's root zone. This annual natural flushing of accumulated salts by rainfall allows the use of much higher salinity levels on citrus in Florida than in arid areas. However, field studies of citrus salinity tolerance generally come from arid areas. Studies concerning growth and yield reductions due to excess salinity are difficult to extrapolate to the sub-tropical conditions of Florida's citrus belt. Actual salinity threshold values pertaining to growth and yield have not been established for Florida conditions. The objective of this investigation was to identify the effects of poor quality irrigation water on the growth of young citrus trees under Florida field conditions.

Florida Agricultural Experiment Station Journal Series No. N-00811. The use of trade names facilitates understanding of this study and does not constitute an endorsement or criticism of the products by the author or the University of Florida.

Materials and Methods

A field study was established at the Agricultural Research and Education Center at Ft. Pierce, Florida. The study was designed as a randomized split plot experiment with irrigation salinity levels and fertilizer treatments as the main effects and rootstocks as split plots. There were 12 salinity-fertilizer combinations (Table 1), each having trees on four rootstocks. Each of the 48 salinity-fertilizer-rootstock combinations was replicated four times.

Double-row beds were constructed in the fall of 1988 in an Oldsmar fine sand soil (sandy, siliceous, hyperthermic, Alfic Arenic Haplaquods). The surface 4-inch layer was a dark gray sand which overlaid a light gray sand. The gray sand turned to white at a depth of 18-24 inches. A spodic (black organic) layer about 4-6 inches thick was located at a depth of 30-36 inches. The subsoil below the spodic layer was a slowly permeable clay. The water furrows were cut to the depth of about 32 inches, with some spodic material brought up to the bed tops.

The pH from soil samples taken prior to bedding averaged 4.9. After bed construction, liming material was broadcast on the bed tops and incorporated into the soil by discing. Dolomite (49% $CaCO_3$ and 36% $MgCO_3$) and calcitic limestone (90% $CaCO_3$) were spread at a rate of 1.2 tons acre^{-1}. In addition, 535 lb acre^{-1} of triple-superphosphate (46% P_2O_5) was broadcast on bed tops and incorporated by discing. A mixture of ryegrass, millet, and bermudagrass was broadcast to establish a ground cover for erosion control on the beds.

The experiment included 12 beds, with each bed having 80 trees. Each bed was divided into 4 plots, each plot with 20 trees. The plots were 10 trees long (in-row) in each of the 2 adjacent rows on the bed. The pair of trees on each end of the plot served as buffers. Rootstock groups (2 trees within-row and the matching trees in the adjacent row) were randomized within each of the plots.

Four levels of irrigation water salinity were included in the experiment. The base water supply was a well in the surficial aquifer with an electrical conductivity (EC) of 0.7 dS m^{-1} (500 ppm). Sea water, obtained from the Ft. Pierce inlet (32 dS m^{-1}), was used to provide the salinization for the other treatments with EC's 2.3, 3.9, or 5.5 dS m^{-1} (1600, 2700, or 3800 ppm). During irrigations, the sea water was injected into the well water with proportional injectors (at 4, 8, and 12%) to obtain the higher salinity levels.

Table 1. Experimental main effect treatment combinations of irrigation salinity levels and fertilizer materials.

Treatment No.	Water salinity (dS m^{-1})	(ppm)	Application method	Treatment ID	N & K applied (lb/yr)
1	0.7	500	Fertigation	L-34	0.34
2	2.3	1600	Fertigation	L-34	0.34
3	3.9	2700	Fertigation	L-34	0.34
4	5.5	3800	Fertigation	L-34	0.34
5	0.7	500	Fertigation	L-23	0.23
6	2.3	1600	Fertigation	L-23	0.23
7	3.9	2700	Fertigation	L-23	0.23
8	5.5	3800	Fertigation	L-23	0.23
9	0.7	500	Broadcast	D-54	0.54
10	2.3	1600	Broadcast	D-54	0.54
11	3.9	2700	Broadcast	D-54	0.54
12	5.5	3800	Broadcast	D-54	0.54

Electric solenoid valves in the irrigation main lines allowed independent control of water to each plot of 20 trees. Water was applied with blue base microsprinklers on stake assemblies which were positioned about 1 foot from the tree trunk. All emitters had young-tree deflectors which confined the discharge, approximately 10.2 gal. h^{-1}, into an area approximately 4 feet in diameter. The deflector plates directed the spray downward and the irrigation water wetted primarily the soil and lower trunks. However, wind drift caused some wetting of the trunk and canopy.

Bare-root 'Ruby Red' grapefruit scion trees budded on sour orange (*Citrus aurantium*) (SO), Carrizo citrange (*Citrus sinensis* × *Poncirus trifoliata*) (CA), Cleopatra mandarin (*Citrus reticulata* Blanco) (CL), and Swingle citrumelo (*Citrus paradisi* × *Poncirus trifoliata*) (SW) rootstocks were planted on 4 April 1989. Tree spacing was 15 feet in-row by 23 feet between-rows, with planting density of 116 trees acre^{-1} on beds that were 50 feet wide.

All treatments were initially irrigated with non-salinized water in order to establish the trees. On 6 June, irrigations with salinized water began. All treatments were irrigated at the same interval and for the same duration. Irrigations, when required, were typically made every other day for 30 minutes. Rainfall shortages made irrigations necessary during each month (Table 2).

An application of 8-8-8 (N-P-K) granular fertilizer with minor elements was applied to all trees at a rate of 1.0 lb tree^{-1} on 10 May. Fertigations began on the L-34 and L-23 plots on 23 June and continued on a weekly basis (19 applicatons) until 7 December. The L-34 and L-23 trees received a total of 0.34 and 0.23 lb N per tree, respectively, The same fertigation schedule and duration was used for both treatments. A 12-0-12 (N-P-K) soultion used on the L-34 trees and a 7-0-7 solution on the L-23 trees, both formulations made from ammmonium nitrate and muriate of potash.

Granular fertilizer was broadcast in a 3-ft diameter circle around the D-54 trees every 6 weeks starting on June 12 and ending on Nov. 28. These 5 applications plus the 10 May application resulted in a total of 0.54 lb of N applied per tree. Dry applications consisted of 1 lb of either 8-8-8 (1 application), 8-4-8 (1) or 10-0-10 (3) analysis granular fertilizer. The primary nutrient sources were ammmonium nitrate and muriate of potash, with diammonium phosphate and sulfate of potash-magnesium used in the formulations with a P component.

On 15 November, 4 leaves were taken from each tree for tissue analysis. The 64 leaves within each rootstock and fertilizer treatment combination were pooled for the tissue

Table 2. Irrigation and rainfall totals by month.

Month	Irrigations number	Irrigations amount (gal./tree)	Rainfall number	Rainfall amount (in.)
Jun.	8	53	9	3.4
Jul.	10	52	9	2.7
Aug.	6	31	11	5.7
Sep.	5	26	12	5.9
Oct.	5	26	11	5.0
Nov.	5	26	7	1.1
Dec.	1	5	4	2.6
Total	40	218	63	26.4

analysis. Leaf analysis was conducted using standard procedures by the University of Florida Analytical Research Lab in Gainesville.

Cultural operations including weed and insect control were identical for all the treatments. Trunk diameter (4 inches above the bud union), tree height, and canopy width were measured on all 768 trees on 14 June and 6 December (48 treatments × 4 replications × 4 trees per plot). *Differences in tree growth* were calculated by dividing the December value of a parameter by the value in June and multiplying by 100 to get percent increase in growth. Canopy volumes were calculated based on the volume of a prolate spheroid as:

$$\mathrm{Vol} = \left(\frac{4}{3}\right)\pi\left(\frac{\mathrm{Ht}}{2}\right)r^2$$

where Vol = canopy volume (ft^3), Ht = tree height (ft), and r = canopy radius (ft). Trunk cross-sectional (X/C) area was calculated as:

$$A = \frac{\pi D^2}{4}$$

where A = the X/C area (in^2) and D = trunk diameter (inches) measured 4 inches above the bud union.

Results were analyzed by standard analysis of variance techniques using Statistical Analysis System computer software (SAS, 1985). Multiple mean separation for rootstocks and fertilizer treatments was accomplished using Duncan's Multiple Range Test at the 95% confidence level (P=0.05). Effects of irrigation water salinity were compared using linear and quadratic contrasts. Salinity and fertilizer effects were analyzed for each rootstock. Overall effects of the main treatments were analyzed using a composite of all water salinity, fertilization, and rootstocks.

The Christmas 1989 freeze reached the Ft. Pierce area during the afternoon of 22 December. The minimum temperature of 22°F was recorded on the morning of 23 December. In the weeks following the freeze, it was apparent that the grove had suffered major damage and continuing the original experiment was futile. About 75% of the trees in the planting were killed or severely damaged by the freeze. The data presented in this paper concerns tree growth performance for the period from when the salinization treatments began in June until just prior to the freeze in December.

Results and Discussion

The 18 inches of rainfall during the usual wet season (June through September) was considerably less than the long-term average of about 40 inches for this period at the Ft. Pierce AREC. Therefore, irrigations were required throughout the summer when rainfall was inadequate. A total of 40 irrigations were required during the months of June through December (Table 2).

The effects of irrigation with the salinized water were visually apparent in most plots. The extent of the damage from the irrigation water ranged from negligible to severe leaf burn and near-complete defoliation. The initiation of summer and fall flushes was delayed on the higher salinity treatments. A heavy rainfall of 1.8 inches on 30 October leached the accumulated salts from the root zones, resulting in vigorous new growth flushes on these plots. This new growth, that had developed during November and December, was especially vulnerable to the freezing temperatures on 23-24 December.

Leaf tissue analysis showed that, within each rootstock, fertilizer treatments affected only leaf N, P, and K content. In contrast, water salinity treatments affected only leaf Cl and Na contents within each rootstock group. Although there were slight differences in leaf Ca and Mg contents between rootstocks, they were not affected by either salinity or fertilizer treatments. Leaf Ca averaged 6.2%, 5.6%, 5.1%, and 4.2% for the CL, CA, SW, and SO trees, respectively. At 0.28%, the leaf Mg concentration for trees on CL was slightly higher than the 0.23% average for trees on other rootstocks.

Chloride toxicity, consisting of necrotic areas on leaf margins, was one of the most common visible salt injury symptoms. Leaf Cl concentrations were directly related to irrigation water salinity level (Table 3), with a significant (P=0.05) linear response for each rootstock. The trees on Carrizo accumulated much more Cl than trees on other rootstocks (Fig. 1). The Cl accumulation of trees on CA at the 0.7 dS m^{-1} salinity level was greater than that for trees on CL and SW rootstocks at the 5.5 dS m^{-1} level. The leaf Cl concentration of over 1.5% for trees on CA with 5.5 dS m^{-1} irrigation water is well above recognized levels where growth reductions occur. Toxicity symptoms usually appear when leaf Cl levels reach about 1% of leaf dry weight (Chapman, 1968) but, based on reductions in yield, leaf Cl concentrations as low as 0.2% can be considered excessive (Koo et al., 1985).

Leaf Na concentrations were also directly related to irrigation water salinity level (Table 3). Highly significant (P=0.01) linear responses were found for each rootstock. Trees on all rootstocks had leaf Na levels of about 0.05-0.06% with the 0.7 dS m^{-1} water. Trees on SO accumulated 0.19% Na at the highest salinity level, followed by trees on CL and SW which each had average leaf Na concentrations of 0.14%. Although trees on CA accumulated the highest Cl levels, they were the most effective at excluding Na, with average leaf Na contents of 0.09 at the 5.5 dS m^{-1} salinity level. Visible sodium toxicity symptoms are known

Table 3. Mean leaf Cl and Na contents by irrigation water salinity for each rootstock (n=3).

Parameter	Water salinity (dS m^{-1})	Rootstock Carrizo citrange	 Cleopatra mandarin	 Sour orange	 Swingle citrumelo
Cl (%)	0.7	0.70	0.18	0.27	0.38
	2.3	0.88	0.21	0.38	0.44
	3.9	1.26	0.29	0.61	0.61
	5.5	1.53	0.63	1.07	0.73
	Linear[z]	**	*	**	*
	Quadratic	n.s.	n.s.	*	n.s.
Na (%)	0.7	0.047	0.050	0.063	0.063
	2.3	0.053	0.057	0.073	0.057
	3.9	0.083	0.090	0.133	0.073
	5.5	0.090	0.143	0.187	0.143
	Linear[z]	**	**	**	**
	Quadratic	n.s.	n.s.	n.s.	**

[z] Linear and quadratic contrasts are nonsignificant (n.s.), or significant at P=0.05 (*) or P=0.01 (**).

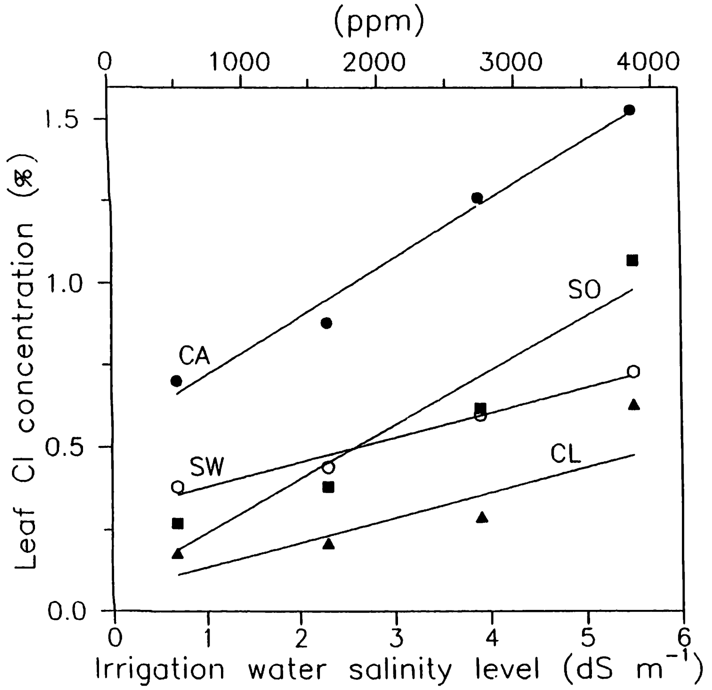

Fig. 1. The change in leaf Cl concentration relative to irrigation salinity level for trees on Carrizo citrange (CA), Cleopatra mandarin (CL), sour orange (SO), and Swingle citrumelo (SW) rootstocks. Linear contrasts of Cl versus salinity are all significant ($P=0.05$, $n=3$).

to appear when leaf Na levels reach 0.10-0.25% of leaf dry weight (Chapman, 1968). Recent studies have shown that high Na in leaves can be physiologically more detrimental than excess Cl (Syvertsen et al., 1988).

The L-23 fertilizer treatments lowered leaf N compared to the other fertilizer treatments for all rootstocks except SW (Table 4). Leaf K percentages tended to be higher in trees with the D-54 treatments and lowest in those with the L-23 treatments. Phosphorous levels showed no trends and were inconsistent with fertilizer treatment.

The June-to-December change in trunk cross-sectional (X/C) area and December canopy volume were selected as the primary indicators of tree response to the imposed treatments. Since the root systems and tops of the trees were all pruned similarly prior to field planting, the December tree growth parameters provided a good indication of the treatment effects. Large canopy volumes result from abundant flushes and vigorous growth, while smaller canopy volumes indicate that the imposed treatments may have limited the growth of the trees.

Highly significant ($P=0.01$) linear responses to irrigation salinity levels were found for trees on each rootstock except SW (Table 5). At the lowest salinity level, trees on SW had the greatest trunk X/C area increase (over 360%) followed by trees on CL at 310% and on CA at 297%. Growth increase was considerably less for trees on SO, averaging 252% with the 0.7 dS m^{-1} water. With the exception of trees on SW, there was about a 15-20% reduction in trunk X/C area change for the 5.5 dS m^{-1} compared to the 0.7 dS m^{-1} irrigation salinity level.

December canopy volumes were highly correlated ($P=0.01$) with irrigation salinity level within each rootstock. Largest canopies were found on trees on CL, with the smallest for trees on SO (Fig. 2). The trees exhibited a 30-40% reduction in canopy volumes for the 5.5 dS m^{-1} compared to the 0.7 dS m^{-1} irrigation salinity level. Canopy growth of trees on CL was least affected by salinized irrigations, while the greatest reductions in growth were found for trees on CA.

It was apparent from the data that the L-23 treatments did not provide adequate nutrition for maximum growth. Fertigations with the higher rate of N (L-34) resulted in the greatest changes in trunk X/C area and largest canopy volumes in December, regardless of rootstock (Table 6). Even though the trees with D-54 fertilization received about 1.7 times more N, the broadcast applications failed to achieve the growth of those trees fertigated at the L-34 level. Averaged across all rootstocks, canopy growth for the D-54 trees was 76%, and trunk X/C area was 86% of the L-34 values. Fertigation at the L-23 level resulted in considerably less growth than the L-34 treatments, with canopy volumes averaging only 56% and trunk X/C area only 79% of L-34 treatment means (Fig. 3).

The growth advantage of the L-34 treatment was greatest at the lowest salinity level (Fig. 4). The average December canopy volume of D-54 trees was about 65% of the L-34 trees for the 0.7 dS m^{-1} treatment. When the salinity increased to 5.5 dS m^{-1}, the difference between these fertilizer treatments was reduced to about 15%. Since the

Table 4. Mean leaf N, P, and K by fertilizer treatment for each rootstock (n=4).

		Rootstock			
Parameter	Fertilizer treatment	Carrizo citrange	Cleopatra mandarin	Sour orange	Swingle citrumelo
Nitrogen	L-34	3.2 a[z]	3.1 a	3.1 a	3.2 a
(%)	L-23	2.7 b	2.3 b	2.6 b	2.9 a
	D-54	3.3 a	3.1 a	3.1 a	3.3 a
Phosphorus	L-34	0.08 b	0.07 b	0.08 b	0.10 a
(%)	L-23	0.09 b	0.08 a	0.13 a	0.12 a
	D-54	0.15 a	0.08 a	0.10 b	0.11 a
Potassium	L-34	0.70 b	0.59 a	0.96 ab	1.23 a
(%)	L-23	0.70 b	0.70 b	0.87 b	1.00 a
	D-54	0.88 a	0.65 ab	1.14 a	1.28 a

[z] Means within columns for the same parameter followed by the same letter are not significantly different ($P=0.05$) according to the Duncan's Multiple Range Test.

Table 5. Mean change in trunk cross-sectional area and December 1989 canopy volume by water salinity for each rootstock (n=48).

		Rootstock			
Parameter	Water salinity (dS m^{-1})	Carrizo citrange	Cleopatra mandarin	Sour orange	Swingle citrumelo
Trunk X/C area change (%)	0.7	297	310	252	364
	2.3	252	273	241	373
	3.9	244	263	231	321
	5.5	240	244	220	366
	Linear[z]	**	**	**	n.s.
	Quadratic	n.s.	n.s.	n.s.	n.s.
Canopy volume Dec. 1989 (ft^3)	0.7	19.1	23.4	8.9	19.0
	2.3	13.0	19.2	8.5	17.3
	3.9	13.1	17.3	6.5	14.0
	5.5	11.4	16.5	5.6	12.7
	Linear[z]	**	**	**	**
	Quadratic	n.s.	n.s.	n.s.	n.s.

[z] Linear and quadratic contrasts are nonsignificant (n.s.), or significant at $P=0.05$ (*) or $P=0.01$ (**).

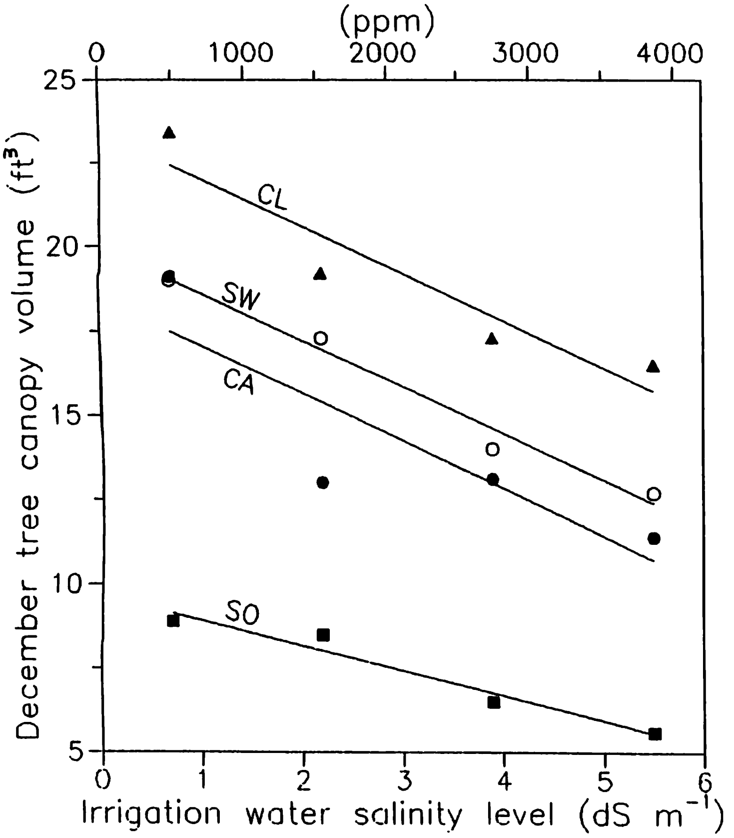

Fig. 2. Reductions in December canopy volumes resulting from salinized irrigation water for trees on Carrizo citrange (CA), Cleopatra mandarin (CL), sour orange (SO), and Swingle citrumelo (SW) rootstocks. Linear contrasts of growth versus salinity are all significant (P=0.01, n=48).

trees receiving the D-54 and L-23 fertilization treatments did not achieve maximum growth, their growth reductions from the higher salinity levels were not as severe as L-34 trees.

Similar linear responses between fertilizer and salinity were found for the change in X/C areas (Table 7). With the 0.7 dS m^{-1} water, the L-34 trees had about 22% and 16% greater increases in X/C area than L-23 and D-54 trees, respectively. Although the L-34 trees had about a 13% reduction in trunk X/C change from the 0.7 to 5.5 dS m^{-1} treatments, the 5.5 dS m^{-1} trunk increases were similar or greater in magnitude to the D-54 and L-23 treatment trees at the 0.7 dS level.

Table 6. Mean change in trunk cross-sectional area and December 1989 canopy volume by fertilizer treatment for each rootstock (n=64).

		Rootstock			
Parameter	Fertilizer treatment	Carrizo citrange	Cleopatra mandarin	Sour orange	Swingle citrumelo
Trunk X/C area change (%)	L-34	306 a[z]	312 a	257 a	395 a
	L-23	216 c	236 c	225 b	326 b
	D-54	253 b	267 b	226 b	347 b
Canopy volume Dec. 1989 (ft^3)	L-34	18.5 a	24.5 a	9.4 a	20.1 a
	L-23	10.2 c	12.3 c	6.1 b	12.5 b
	D-54	13.8 b	20.5 b	6.6 b	14.7 b

[z] Means within columns for the same parameter followed by the same letter are not significantly different (P=0.05) according to the Duncan's Multiple Range Test.

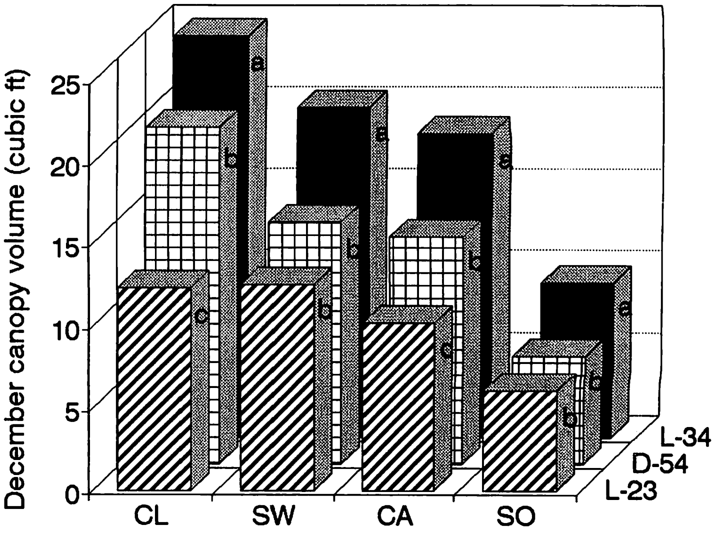

Fig. 3. December canopy volumes by fertilizer treatment for trees on each rootstock. Bars with the same letter within each rootstock are not significantly different according to Duncan's Multiple Range Test (P=0.05, n=64).

Conclusions

The data presented are only for the first season of growth and comes from a year that had less than half the normal summer rainfall, resulting in higher than normal salinity stress induced by irrigation water. However, the results do present some interesting trends concerning salinity and fertilizer effects on young grapefruit trees.

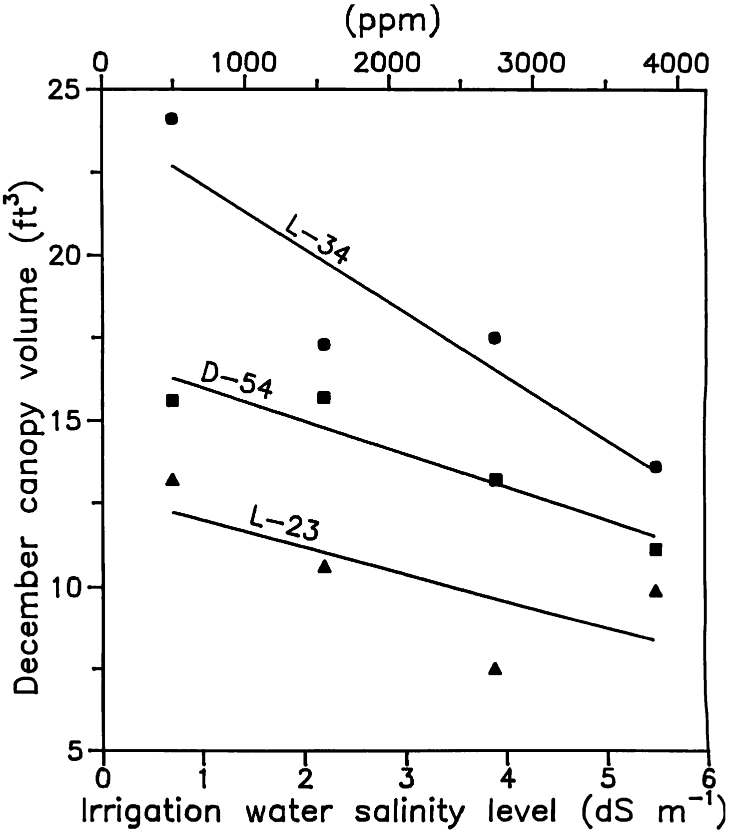

Fig. 4. Relationship between fertilizer treatments and irrigation water salinity level. Linear contrasts of growth versus salinity are all significant (P=0.05, n=64).

Table 7. Mean change in trunk cross-sectional area and December 1989 canopy volume by irrigation salinity for each fertilizer treatment (n=64).

Parameter	Water salinity (dS m^{-1})	Fertilizer treatment L-34	Fertilizer treatment L-23	Fertilizer treatment D-54
Trunk X/C area change (%)	0.7	342	280	296
	2.3	319	252	283
	3.9	311	238	262
	5.5	298	233	251
	Linear^z	*	**	**
	Quadratic	n.s.	n.s.	n.s.
Canopy volume Dec. 1989 (ft^3)	0.7	24.1	13.2	15.6
	2.3	17.3	10.6	15.7
	3.9	17.5	7.5	13.2
	5.5	13.6	9.9	11.1
	Linear^z	**	**	**
	Quadratic	n.s.	**	n.s.

^{z}Linear and quadratic contrasts are nonsignificant (n.s.), or significant at P=0.05 (*) or P=0.01 (**).

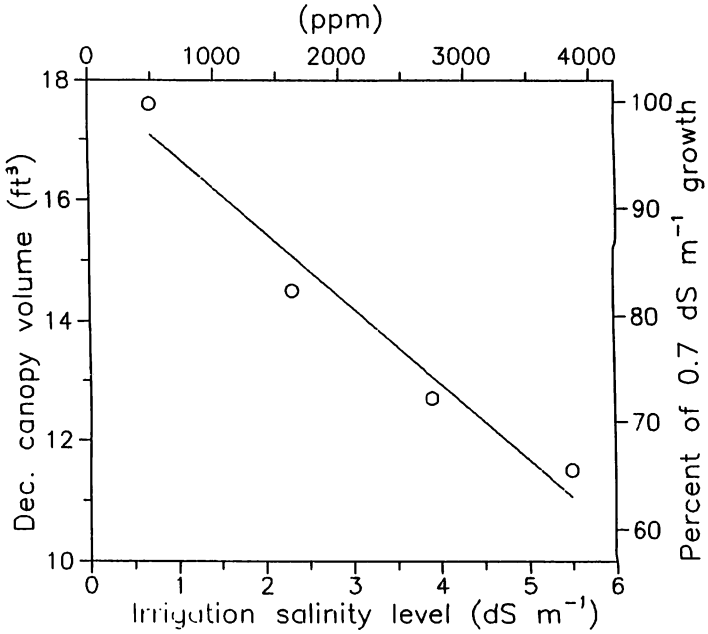

Fig. 5. December canopy volumes and the reduction in growth relative to the 0.7 dS m^{-1} (500 ppm) irrigation water for all rootstocks and fertilizer treatments combined (n=192).

Irrigation water salinity may be a major limiting factor for citrus production in many Flatwoods groves. In this study, and in numerous other laboratory and arid-area field studies, significant growth reductions were found when higher salinity irrigation water was used. When the data for all 4 rootstocks were averaged, the trees irrigated with the 0.7 dS m^{-1}water had average canopy volumes of 17.6 ft^3. In contrast, the trees watered with salinized water had average canopy volumes of 14.5, 12.7, and 11.5 ft^3, respectively for the 2.3, 3.9 and 5.5 dS m^{-1} treatments (Fig. 5). This translates to reductions in canopy volumes of about 7% for each 1.0 dS m^{-1} increase in irrigation water salinity level above the base level of 0.7 dS m^{-1} (about 10% for each 1000 ppm above 500). The economic factors associated in using poor quality irrigation water need to be considered. For instance, extended irrigation of young trees with 3.6 dS m^{-1} (2500 ppm) water could result in about a 20% reduction in growth compared to using low salinity water. Although this decrease may not be as severe during years with normal precipitation, there is a potential for substantial growth decreases resulting from high salinity.

There are known differences in salinity tolerances of rootstocks (Wutscher, 1979) and trees on all rootstocks in this test either had excessive leaf Na or Cl accumulations at the highest salinity levels. Trees on CL were able to exclude Cl better than other rootstocks and the order of Cl accumulation was similar to other reports (Cooper, 1961; Chapman, 1968; Newcomb, 1968). Even at the lowest salinity level trees on CA accumulated high levels of Cl, but they were effective at excluding Na. Trees on CL had the greatest growth and those on SO had the least. Growth of trees on SW was slightly more than on CA, but both were about 15-20% less than trees on CL.

Unlike a recent study which showed no difference between fertigation compared to conventional fertilization at the same annual rates for first-year 'Hamlin' orange trees (Willis et al., 1990), this experiment showed a definite advantage for first-year grapefruit trees using the L-34 fertigation rate. Comparisons between L-34 and D-54 treatments are difficult to extrapolate since the N rates differed. However, the L-34 fertigation (0.34 lb N yr^{-1}) proved superior to the other fertilization methods for all growth measurements. Growth was greater for the L-34 treatments even though the total seasonal N application was only 63% of the broadcast fertilizer (D-54) rate. This advantage was apparent in all rootstocks at all salinity levels. With any young-tree fertilizer program, consideration should be given to tree size and growth potential when deciding upon rates.

Where high salinity irrigation water is used, soil moisture must be maintained at high levels to ensure that salts do not accumulate and concentrate. Irrigation management using high salinity water requires frequent over-irrigation to leach accumulated salts below the root zone. These irrigations will leach fertilizer nutrients as well as the toxic Cl and Na salts. Properly applied fertigations should reduce the potential for leaching of nutrients compared to traditional broadcast application of granular fertilizer and result in more efficient fertilizer use.

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EFFECTS OF SALINITY AND CALCIUM ON SEEDLING EMERGENCE, GROWTH, AND SODIUM AND CHLORIDE CONCENTRATIONS OF CITRUS ROOTSTOCKS

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Abstract. **Salt tolerance of several citrus rootstocks during germination, emergence, and early seedling stage was studied under greenhouse conditions. Salinity delayed and depressed seedling emergence, reduced seedling biomass, and altered mineral status of young citrus seedlings. However, magnitude of these parameters varied among rootstocks. The addition of 50 mol m^{-3} NaCl to a nutrient solution delayed seedling emergence by 3 to 5 days with the exception of Troyer citrange (TC) which emerged the soonest beginning at day 10 after sowing. Final emergence was reduced by less than 30% in Carrizo citrange (CC), TC, and Swingle citrumelo (SC), and by more than 65% in Ridge pineapple (RP), Cleopatra mandarin (CM), and rough lemon (RL). Total seedling biomass was reduced by over 50%. The addition of NaCl increased Na and Cl in the shoots and roots of all rootstocks. The addition of 5 mol m^{-3} $CaSO_4$ to the saline solution enhanced the emergence of the first seedling in CC, CM, and RL, improved final emergence in SO, SC, RP, CM, and RL, and improved seedling growth of SC and RL. For citrus, no uniform trend was found in the relationship between salt tolerance during emergence and during seedling growth. Salt tolerance at emergence may not be a useful indicator for rapid screening of citrus cultivars.**

Citrus rootstocks are propagated mostly from seeds. Although modern techniques place an increasing emphasis on plant uniformity and the importance of seeds in the overall citrus nursery operation (Castle, 1981), there are only 2 reported studies of water stress involving the effect of polyethylene glycol (PEG) on citrus seedling emergence (Chilembwe et al., 1992; Kaufmann, 1969) and only one study dealing with the effect of PEG, NaCl, and Na_2SO_4 on citrus germination (Mobayen and Milthorpe, 1978).

Soil salinity may reduce seed germination by reducing water uptake by seeds or by allowing seeds to absorb excessive ions that are potentially toxic (Ayers and Hayward, 1948). These physico-chemical effects may reduce germination and the emergence of seeds. Salt stress may have different effects on seed germination and young seedling growth. Some crops, such as alfalfa and sugar beets, are relatively tolerant to salinity during the later stages of growth but are sensitive to salinity during germination (Ayers and Hayward, 1948). Other crops, such as rice, are much more salt sensitive during the young-seedling stage of development than during germination (Pearson et al., 1966). In citrus, it is not known whether salt tolerance during germination or seedling emergence is related to tolerance during later growth stages.

The effect of salinity on citrus seedling emergence has not been well investigated, and information on the tolerance of citrus seedlings at early stages is lacking. Therefore, a study was initiated to evaluate the effect of salinity on seedling emergence and early stages of seedling development of various citrus rootstocks. Another objective of this work was to investigate the potential improvement in seedling emergence under saline conditions due to supplemental Ca because $CaSO_4$ has been found to alleviate the adverse effects of NaCl on citrus tree growth (Zekri and Parsons, 1990).

Materials and Methods

The experiment was carried out in a greenhouse in which the temperature and relative humidity ranged from 16 to 34°C and from 50 to 100%, respectively. The tested rootstocks were sour orange (*Citrus aurantium*) (SO), Volkamer lemon (*C. volkameriana*) (VL), Ridge Pineapple sweet orange (*C. sinensis*) (RP), Cleopatra mandarin (*C. reshni*) (CM), rough lemon (*C. jambhiri*) (RL), Carrizo (CC) and Troyer citranges (TC) (*C. sinensis* × *Poncirus trifoliata*), and Swingle citrumelo (*C. paradisi* × *P. trifoliata*) (SC).

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