Managing Salinity in Florida Citrus

Brian Boman
Trees receiving 40 gal/day of 2000 ppm water will receive $4\frac{3}{4}$ lb of salt per week.
Evaporation
- Pure water
- Salts accumulate at surface

Concentration
- As soil dries, ppm in water increases

Removal
- Leaching only way to remove
• Canopy thinning
• Leaf drop at extremities
• Delayed flush & bloom
• Burn on edges of leaves
• Bronzing of leaves
• Twig dieback
• Small leaves
• Bark burn on young trees
• Small fruit
Leaf Burn

- Wetting foliage can cause severe leaf damage
- Cl and Na in lower leaves can be much higher
- Leaf burn can occur at about 0.25% Na or Cl
- Accumulation depends on evaporation rate, which results in increased salt concentration of the water film on the leaves.
- Damage greater from intermittent than continuous wetting - nighttime irrigation preferred
Osmotic Stress

- Salts reduce the availability of free water through both chemical and physical processes.
- Roots cannot extract as much water from a solution that is high in salts.
- Trees have to work harder to move water into the roots.
Young Trees

40 irrigations from June-Dec

D = 1 lb/tree 8-0-8 at 6-wk intervals (0.54 lb)

L = 19 fertigations at 1-wk intervals (0.23 or 0.34 lb)
10% growth reduction for each 1000 ppm
‘Valencia’ – rough lemon

- Planted in 1986
- Single beds – 15 X 30 ft (97 trees/ac)
- Oldsmar fine sand soil
- Microsprinkler – salinity began in 1996
  - 500, 1500, 2500, 3500 ppm – proportional injectors
  - Brine from NaCl (55%), CaCl (34%), and KCl (11%)
- 6 trees/plot – 6 reps
- Blight problem – 2 trees/rep analyzed
0.10% increase in leaf Cl for each 1000 ppm increase in salinity.
Average number of fruit size 100 and larger for 1998/99 through 2000/01 seasons
Yields for 1996/97 through 2000/01 seasons
Valencia
96/97 - 00/01 seasons

Cumulative yield (boxes/tree)

Salinity level (ppm)

(boxes/acre)
TSS for 1996/97 through 2000/01 seasons
3.8 lb TSS/tree per year reduction for each 1000 ppm increase in salinity (370 lb/ac/yr @ 97 tree/ac)
5-yr Avg Yield: 490 box/ac/yr (500 ppm)

0.6 box/tree/yr reduction for each 1000 ppm salinity (11%)

60 box/ac/yr for each 1000 ppm @ 97 trees/ac

3340 lb TSS/ac/yr (500 ppm)

3.8 lb TSS/tree/yr for each 1000 ppm salinity (11%)

360 lb TSS/ac/yr for each 1000 ppm salinity @ 97 trees/ac
Little effect on internal juice quality

- Differences masked by climatic swings (i.e. heavy rains, hot & dry to cool and wet)
- No differences in solids/box or Brix:acid ratio at time of harvest
- TSS averaged 6.7-6.8 lb/box for the 5 seasons
- Ratio averaged 13.7, 13.9, 13.6, and 13.5 for 500, 1500, 2500, and 3500 ppm, respectively

Except for 97/98, salinity decreased both No. & fruit size

About 11% reduction in boxes and TSS for each 1000 ppm increase in TDS

Study period represents above, below, and average rainfall years

Detrimental effects could be greater with less management effort
‘Ray Ruby’ Grapefruit

- Planted in 1990
- 50’ double beds – 15 X 24’ (116 tree/ac)
- Oldsmar fine sand soil
- Microsprinkler irrigation
  - 500, 1600, 2700, 3800 ppm
  - Sea water mixed with surficial aquifer well water
- 4 trees/plot – 4 reps
- Fertilized Feb, May, Oct (140-150 lb N/ac)
0.2% increase in leaf Cl for each 1000 ppm TDS increase
0.03% increase in leaf Cl for each 1000 ppm TDS increase.
Yield reductions from 500 to 3800 ppm:

- 97/98 – 40%
- 98/99 – 30%
- 99/00 – 54%
- 00/01 – 91%
Yield reductions from 500 to 3800 ppm:

97/98 – 0%
98/99 – 37%
99/00 – 18%
00/01 – 72%
Fruit Size

Carrizo citrange

Fruit size 36 and larger (number/tree)

60  90  120  150  180

TDS (ppm) 500 1600 2700 3800

a  b  c  c

Swingle citrulemo

Fruit size 36 and larger (number/tree)

60  90  120  150  180

TDS (ppm) 500 1600 2700 3800

a  b  ab  b
35 box/ac/yr (Swingle) to 45 box/ac/yr (Carrizo) reduction for each 1000 ppm increase in TDS
240 lb/ac/yr (Swingle) to 300 lb/ac/yr (Carrizo) reduction for each 1000 ppm increase in TDS (5-6%)
Carrizo: 300 lb TSS/ac/yr for each 1000 ppm TDS (6%)

Swingle: 240 lb TSS/ac/yr for each 1000 ppm TDS (5%)

Carrizo: 50 box/ac/yr for each 1000 ppm TDS (11%)

Swingle: 40 box/ac/yr for each 1000 ppm TDS (9%)
Little effect on internal juice quality

- Carrizo Ratio averaged 9.1, 8.8, 9.0, and 8.9 for 500, 1500, 2500, and 3500 ppm, respectively
- Swingle Ratio averaged 8.2, 8.5, 8.6, and 8.5 for 500, 1500, 2500, and 3500 ppm, respectively
- Solids/box averaged 4.7 lb for Carrizo and 4.9 lb for Swingle

5-6% (240-300 lb/ac) reduction in TSS and 9-11% (40-50 boxes/ac) reduction in boxes for each 1000 ppm increase in TDS

In 2000, CA w/ 500 ppm had 50% more size 36+ than 2700 or 3800 ppm while SW w/500 ppm had 1.5-2.0 times as many size 36+ as those with 1600 or more ppm

Study period represents above, below, and average rainfall years -- Detrimental effects could be greater with less management effort
Irrigation Management
Inches/day → gal/day

Gal/tree/day = ET x spacing x 0.622

For ET = 0.16 in/day
and 12 ft x 24 ft spacing:

Gpd/tree = 0.16 x 12 x 24 x 0.622
= 29 gal/tree/day
ET calculated from Kc and Long-Term Penman ETo for 12 ft x 24 ft spacing (151 trees/acre)

- **Tampa**: Blue line
- **West Palm Beach**: Red line
- **Lakeland**: Green line
- **Kc**: Brown dashed line

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>Daily ET (gal/day)</td>
<td></td>
<td></td>
<td></td>
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<td>Kc</td>
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</tr>
</tbody>
</table>

- **Jan**: 5
- **Feb**: 5
- **Mar**: 5
- **Apr**: 5
- **May**: 5
- **Jun**: 5
- **Jul**: 5
- **Aug**: 5
- **Sep**: 5
- **Oct**: 5
- **Nov**: 5
- **Dec**: 5

- **Kc January**: 0.8
- **Kc November**: 1.1

**Legend:**
- Daily ET: gallons per day
- Kc: Constant for crop growth
- Tampa
- West Palm Beach
- Lakeland
- Kc

**Graph Key:**
- X-axis: Months
- Y-axis: Daily ET (gal/day)
- Kc (Y-axis): 0.8 to 1.1
## Water use in gal/tree for various planting densities assuming equivalent per-acre water use.

<table>
<thead>
<tr>
<th>ET (in/day)</th>
<th>Tree spacing (ft x ft)</th>
<th>Tree area (ft(^2))</th>
<th>Tree density (trees/acre)</th>
<th>ET (gal/tree/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>8 x 22</td>
<td>176</td>
<td>248</td>
<td>11</td>
</tr>
<tr>
<td>0.10</td>
<td>10 x 24</td>
<td>240</td>
<td>182</td>
<td>15</td>
</tr>
<tr>
<td>0.10</td>
<td>15 x 25</td>
<td>375</td>
<td>116</td>
<td>23</td>
</tr>
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<td>0.15</td>
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<td>248</td>
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<td>46</td>
</tr>
</tbody>
</table>
Root system most prolific in A horizon and lacking in overburden (Riviera series)

Source: Rootstock and Soil Interactions Project, Bauer, Castle, Boman, and Obreza
Wetted diameter = 3.6 m (12 ft)
Managed Root depth = 25 cm (10”)

Vol_{water} = Vol_{soil} \times AWC
= 2550 \times 12\% = 306 L
= 80.8 gal

50\% depl = 306 L \times 0.5
= 153 L = 40.4 gal

33\% depl = 306 \times 0.33
= 102 L = 27 gal

2:42 for 10 gph emitter

Area = \frac{3.14 \times d^2}{4}
= \frac{3.14 \times 3.6^2}{4}
= 10.2 m^2 = 110 ft^2

Vol_{soil} = \text{area} \times \text{depth}
= 10.2 m^2 \times 0.25 m = 2.55 m^3
= 2550 L = 90 ft^3

Vol_{water} = Vol_{soil} \times AWC
= 2550 \times 12\% = 306 L
= 80.8 gal
Flatwoods Soils

WHC of ~0.08 in/in is typical for most Flatwoods soils (exceptions: Winder, Chobee, soil mixing, etc.)

<table>
<thead>
<tr>
<th>Root Depth</th>
<th>WHC</th>
<th>1/3 Depl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>0.72 in</td>
<td>0.24 in</td>
</tr>
<tr>
<td></td>
<td>79 gal</td>
<td>26 gal</td>
</tr>
<tr>
<td>12</td>
<td>0.96 in.</td>
<td>0.33 in</td>
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<tr>
<td></td>
<td>106 gal</td>
<td>35 gal</td>
</tr>
<tr>
<td>18</td>
<td>1.44 in</td>
<td>0.48 in</td>
</tr>
<tr>
<td></td>
<td>158 gal</td>
<td>52 gal</td>
</tr>
</tbody>
</table>
Salts in sandy soils are flushed out fairly quickly following rainfall of 1+ inches.

Salinity levels at a depth of 18 inches dropped to near zero following rains beginning April 13.

The rains on April 30 flushed out the salts from the 24 inch depth.

Salts were flushed from the profile and were found to build in the water furrow.

Irrigations every 2-3 days beginning on May 9 increased soil salinity at 18 and 24 inch depths.
Salinity Management

Salt concentration is higher in soil than in applied water

- Plant transpiration
- Soil surface evaporation
- Selectively remove relatively pure water

Salt accumulations removed only by leaching

Key is keeping a net downward flow in the root zone

Accumulation over years is not a problem in most cases

Salts in sandy soils leached out with the first 1” of rain
• Sensitivity to injury from direct foliar contact bears no relationship to general soil salinity tolerance.

• Trees on all rootstocks are about equally sensitive to injury through direct foliar contact.

• Young, tender shoots are especially vulnerable to salt burn

Young trees on Swingle are more susceptible to spray on their trunks, and often develop brown “blisters” of dead tissue on their trunks.
The frequency of injecting nutrients or applying granular fertilizer has a direct effect on the concentration of TDS in the soil solution.

- Frequent applications with relatively low concentrations of salts will normally result in less salinity stress than programs using only 2-3 applications per year.

- Controlled-release fertilizers and frequent fertigations are ways to economically minimize salt stress when using high salinity irrigation water.

Selecting nutrient sources that have a relatively small osmotic effect in the soil solution can help reduce salt stress.
The Cl in KCl or Na in NaNO₃ materials add more toxic salts to the soil solution.

High rates of salt application can alter soil pH and thus cause soil nutrient imbalances.

Na displaces K, and to a lesser extent Ca, in soil solutions.

- Can lead to K deficiencies
- In some cases, even Ca deficiencies

Imbalances can compound the effects of salinity stress.

Problems can be minimized if adequate nutritional levels are maintained.
Salinity Management

If TDS over 1200 ppm or Cl > 250 ppm, salinity management needs to be considered

- Winter – most years there is little concern
  - Low ET
  - Least sensitive period
- Spring dry season
  - Irrigate daily in April - June
  - Apply enough water to wet entire root zone depth
  - Extra flushing every other week
- Summer/Fall - salinity management needed in some years
  - If successive irrigations are required, irrigate frequently with sufficient water to keep salts moving downward
Summary

• Expect yield decreases of about 10% for each additional 1000 ppm increase in TDS

• Significantly smaller overall fruit size during years where irrigation is necessary

• Expect significant leaf loss due to Cl accumulation

• Frequent irrigations minimize effects of salinity

• Irrigation amount must be great enough to flush salts downward – water should seep into water furrow

• Monitor irrigation water salinity and soil moisture status during irrigation season

• Fertigation can be very effective during droughts
Managing Salinity in Florida Citrus
B. J. Boman and E. W. Stower

Introduction

The usual focus of citrus irrigation is to maintain water in the root zone in a range suitable for optimum crop growth. However in some areas, salinity management may become the major objective of irrigation management. Irrigation with high salinity water requires irrigations to be more frequent and of greater amounts than when good quality water is used. During extended droughts, salinity levels will dictate irrigation scheduling.

In some coastal areas, well water can be attributed to fresh water zone I pumping rate in the effect of groundwater intrusion. Salt water contamination of fresh water sources is illustrated in Fig.

Outline for Managing Irrigation of Florida Citrus with High Salinity Water
B. J. Boman and E. W. Stover

Salinity Management

Salinity management is sometimes an important component of irrigation management. High levels of salts in irrigation water can compromise water relations in citrus trees, resulting in water stress even when soils have a relatively high water content. Irrigation with high salinity water requires more frequent applications and a greater volume than when...