Advanced Citrus Production Systems: What You Need to Know to Install a System Today

Arnold Schumann, Kevin Hostler, Kelly Morgan, Jim Syvertsen, Bill Castle (UF/IFAS, CREC & SWFREC)

Fluid Fertilizer Workshop
TUESDAY, 8 DECEMBER 2009
Tampa, FL
What is an “Advanced Citrus Production System” (ACPS)?

- ACPS borrows advanced fertigation + higher density planting from “Open Hydroponics”
  
- Main goals are early, high production, early return on investment, disease avoidance?, longevity. Built-in redundancy compensates for HLB-removal and canker infection
  
- Other goals: Increased water and nutrient use efficiencies (partial rootzone drying), reduced environmental impacts
  
- Good flush protection, especially psyllid control is essential during establishment phase
  
- Synonymous with computerized fertigation, using pulsed drip emitters, frequent monitoring and remote control
Main components of an ACPS

1. Intensive fertigation
2. Balanced, complete nutrition
3. High density planting

Monitoring equipment

Computer control

N, P, K, Ca, Mg, S, Mn, Fe, Zn, Cu, B, Mo, Cl (100 ppm nitrogen)
Steps being used to implement ACPS in Florida

- Keep soil near field capacity (~zero water tension) with short duration frequent (drip) irrigations to wet the top 18 inches of soil
- Inject fertilizer with most irrigations (100 ppm N)
- Use complete balanced nutrient formula
- Skip fertigation on rainy days, while soil is already near field capacity
- Flush excess salts during the dry season with plain irrigation (3 to 4x normal irrigation amount every 2 weeks)
Soil wetting with drip irrigation

Candler soil - overhead view
Volumetric water content % for 8-inch depth of soil.

Drip line direction

Pulse drippers 11:30am (pulsing at the time)

<table>
<thead>
<tr>
<th>inches</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>2.9</td>
<td>3.2</td>
<td>4.3</td>
<td>5.9</td>
<td>7.3</td>
<td>11.5</td>
<td>11.5</td>
</tr>
<tr>
<td>10</td>
<td>8.7</td>
<td>8.7</td>
<td>9.5</td>
<td>5.7</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>8</td>
<td>12.0</td>
<td>15.4</td>
<td>12.0</td>
<td>8.7</td>
<td>8.7</td>
<td>8.7</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Daily drippers 11:45am (23 h since previous irrig)

<table>
<thead>
<tr>
<th>inches</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>3.2</td>
<td>2.6</td>
<td>3.4</td>
<td>4.3</td>
<td>5.7</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>10</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>8</td>
<td>4.8</td>
<td>5.1</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Drip line direction
Replant configuration - Ridge

- Ridge
- Drip irrigation line
- Drip emitters 15” apart
- Tree T-Pee®, 2’ diameter (optional)
- Wetted soil and roots
- Water / EC sensor
- Young citrus tree
- Sensors: 0-4” depth, 18” depth
- Sandy soil
Typical fertigation system

Drip or MS system

1

2

3

Solenoid valves

Injection ports

Check valve(s)

Flow meter

200 mesh filter

Flow meters

Filters

Fertilizer Tank A

Fertilizer Tank B

Injection pumps
Balanced nutrition – 13 elements

<table>
<thead>
<tr>
<th></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>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>P</td>
<td>14.3</td>
<td>14.3</td>
<td>15.7</td>
<td>15.7</td>
<td>15.7</td>
<td>20.0</td>
<td>20.0</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>K</td>
<td>57.1</td>
<td>57.1</td>
<td>71.4</td>
<td>85.7</td>
<td>85.7</td>
<td>100.0</td>
<td>108.3</td>
<td>140.0</td>
<td>140.0</td>
<td>120.0</td>
</tr>
<tr>
<td>for bloom</td>
<td>Ca</td>
<td>100.0</td>
<td>100.0</td>
<td>85.7</td>
<td>85.7</td>
<td>57.1</td>
<td>33.3</td>
<td>33.3</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td></td>
<td>Mg</td>
<td>14.3</td>
<td>14.3</td>
<td>17.1</td>
<td>20.0</td>
<td>17.1</td>
<td>20.0</td>
<td>23.3</td>
<td>28.0</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>20.6</td>
<td>20.6</td>
<td>24.6</td>
<td>24.6</td>
<td>28.7</td>
<td>33.7</td>
<td>40.4</td>
<td>34.4</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>Fe</td>
<td>1.714</td>
<td>1.714</td>
<td>1.714</td>
<td>1.714</td>
<td>2.000</td>
<td>2.000</td>
<td>2.400</td>
<td>2.400</td>
<td>2.400</td>
</tr>
<tr>
<td></td>
<td>Mn</td>
<td>0.857</td>
<td>0.857</td>
<td>0.857</td>
<td>0.857</td>
<td>0.857</td>
<td>1.000</td>
<td>1.000</td>
<td>1.200</td>
<td>1.200</td>
</tr>
<tr>
<td>for bloom</td>
<td>Zn</td>
<td>0.857</td>
<td>0.857</td>
<td>0.571</td>
<td>0.286</td>
<td>0.286</td>
<td>0.333</td>
<td>0.333</td>
<td>0.400</td>
<td>0.800</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>0.029</td>
<td>0.029</td>
<td>0.029</td>
<td>0.029</td>
<td>0.029</td>
<td>0.033</td>
<td>0.033</td>
<td>0.040</td>
<td>0.040</td>
</tr>
<tr>
<td>for bloom</td>
<td>B</td>
<td>0.857</td>
<td>0.857</td>
<td>0.571</td>
<td>0.286</td>
<td>0.286</td>
<td>0.333</td>
<td>0.333</td>
<td>0.400</td>
<td>0.400</td>
</tr>
<tr>
<td></td>
<td>Mo</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.023</td>
<td>0.023</td>
<td>0.028</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>Cl</td>
<td>49.7</td>
<td>49.7</td>
<td>62.0</td>
<td>62.0</td>
<td>68.3</td>
<td>87.0</td>
<td>94.0</td>
<td>121.6</td>
<td>121.6</td>
</tr>
</tbody>
</table>

- Final nitrogen concentration ~ 100 ppm
- Focus on bloom enhancement and fruit set
- Manipulate leaf flushes?
- Avoid leaching in summer rainy period
Computerized control and monitoring

<table>
<thead>
<tr>
<th>NMC-JR Irrigation</th>
<th>Block9</th>
<th>Gapway</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm</td>
<td>OFF</td>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>07-Jun-09</td>
<td>07-Jun-09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>10:16:11</td>
<td>10:14:20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program</td>
<td>PAUSE</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valve</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle Actual</td>
<td>N/A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle Set</td>
<td>1 of 1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Actual</td>
<td>N/A</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Set</td>
<td>50.0</td>
<td>80.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate Actual</td>
<td>N/A</td>
<td>19.496</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate Set</td>
<td>12.480</td>
<td>16.400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC Actual</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC Set</td>
<td>Not Set</td>
<td>Not Set</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH Actual</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH Set</td>
<td>Not Set</td>
<td>Not Set</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>OFF</td>
<td>ACTIVE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dosing</td>
<td>OFF</td>
<td>ACTIVE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtration</td>
<td>OFF</td>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misting</td>
<td>OFF</td>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td>OFF</td>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Program Start At</td>
<td>11:40:00</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Program Time Remain:</td>
<td>01:23:49</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Progress and selected results

Ridge - 16 December  2008 (0 weeks)
Ridge - 13 August 2009 (+32 weeks)

Conventional

Drip fertigation
Conventional  MS fertigation  Drip fertigation

Standard practice: 6x granular fertilizer per year; Infrequent irrigation with microsprinklers

Microsprinkler fertigation: Nearly daily fertigation of balanced nutrients with microsprinklers

Drip fertigation: Nearly daily fertigation of balanced nutrients with drippers
Ridge – 7 December 2009 (+1 year)

MS fertigation

Conventional

Drip fertigation
Ridge – 7 December 2009 (+1 year)

Canopy volume (feet³/tree)

LSD(0.05)

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Canopy volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drip fertigation, Swingle [10x20]</td>
</tr>
<tr>
<td>2</td>
<td>Drip fertigation + OM, Swingle [10x20]</td>
</tr>
<tr>
<td>3</td>
<td>MS fertigation, Swingle [10x20]</td>
</tr>
<tr>
<td>4</td>
<td>MS fertigation, Swingle [8x18]</td>
</tr>
<tr>
<td>5</td>
<td>Drip fertigation, Swingle [10x20]</td>
</tr>
<tr>
<td>6</td>
<td>Drip fertigation, C-35 [8x18]</td>
</tr>
<tr>
<td>7</td>
<td>Drip fertigation, C-35 [8x15]</td>
</tr>
</tbody>
</table>
Early results from ACPS in Florida (7.5 months age)

Average growth rates are doubled
Early production – growth acceleration

Feasibility testing - extrapolating from current monthly growth rates

**Economically productive size** at a given planting density

**2.25 years!**
Early production – putting it all together

Growth acceleration + **high density**, using simplified economics

Conventional 15 x 20 ft spacing = 145 tpa
Conventional production methods = 250 boxes/ac at 5 years*
    = 1.72 boxes/tree

*economically viable production point (250 boxes/ac x $5.5/box = $1,375 /ac); assuming production costs at $1,300 /ac

ACPS production methods = 1.72 boxes/tree at 2.5 years
ACPS 8 x 18 ft spacing = 303 tpa
ACPS production = 1.72 x 303 = 521 boxes/ac at 2.5 years
ACPS fruit revenue = 521 boxes/ac x $5.5/box = **$2,866 /ac**
Water applied to young trees - Ridge

Sensor-based MS fertigation (108%)

Conventional MS (grower; 100%)

Sensor-based drip fertigation (61%)
(85% @303 tpa; 102% @363 tpa)

(Water use by drip irrigation would be 23% relative to conventional 100% if tree cones had not been used)
N applied to young trees - Ridge

Leaf N>3%; NS

Conventional (grower; 100%); similar to IFAS recommendations

Drip (13.5%) and MS fertigation (22%)
(18.8% @303 tpa; 22.5% @363 tpa)
Pulse drip fertigation - Ridge

After 9 months (March to December 2008)
Average 550 boxes/ac (up to 5 boxes per tree)
Pulse drip fertigation - Ridge
Water applied to mature trees - Ridge

Conventional ET-based MS (100%)

Sensor-based MS (40%)

Sensor-based drip (29%)
Problems – salt accumulation
Problems – salt accumulation 
- from drip fertigation

Salt accumulation in absence of rain; 
Remedy: leach with 3 to 4x regular irrigation amount every 2 weeks
Problems – Psyllid control

More frequent pest control will be required to protect the constantly flushing young trees.
Precision spraying for IPM

Reduce production costs, extend the use of rate-limited products, especially at high planting density
Problems – N deficiency in spring

Daily fertigation may not cope with high nutrient demand of mature trees; SOLUTION: Apply 15 to 25% of annual fertilizer as dry granular in February
Possible alternatives? – controlled release fertilizers

Using nursery-grade coated granular fertilizer

1.73-inch trunk diameter @ 16 months
Welcome to the Advanced Citrus Production System Web Site

What is the Advanced Citrus Production System (ACPS)?

The ACPS incorporates elements of "open hydroponics" or intensive fertigation, high planting density, and a suitable rootstock capable of developing a compact tree and an efficient root system in the fertigated zone. Other enhancements are being added through research.

Citrus Research and Education Center
700 Experiment Station Rd.
Lake Alfred, FL 33850
http://www.crec.ifas.ufl.edu
Demonstration blocks (1/2) in commercial growers’ groves (Schumann, Hostler, Castle, Spann)
Conclusions

- For mature trees, a hybrid method of pre-bloom granular fertilization (15-25%) followed by intensive fertigation is proposed.
- Water and fertilizer use is reduced by drip fertigation.
- Salinity must be managed in the dry season.
- Mature trees can be converted in one year to drip fertigation on the Ridge.
- Intensive microsprinkler fertigation improves over conventional microsprinkler irrigation + granular fertilization; drip fertigation is better.
- Rootstock differences are large and exploitable.
- Data from planting densities will only be available after more years.
Summary

High density planting (300+ tpa)

Accelerated growth rates (with intensive fertigation, balanced nutrition)

Early, profitable yields

HLB Canker

Other diseases

Built-in redundancy (“spare” trees)

Sustained, profitable yields

Enhanced tree vigor (longevity, disease tolerance?)
Summary

- Growth acceleration for early production using intensive fertigation and balanced nutrition, is an essential component of the ACP package.

- Without earlier yields, high density planting alone would not likely recover the costs of production, shown in past experiments.
ACPS, based on OHS, appears to work well in Florida conditions

ACPS is based on conventional Biology, Chemistry, Physics
Acknowledgements

Kirandeep Mann, Laura Waldo, Davie Kadyampakeni

Gapway Groves

Florida Citrus Production Research Advisory Council

Southwest Florida Water Management District

Florida Agricultural Experiment Station