Introduction

- **Fertigation** is used to apply soluble fertilizer and irrigation water simultaneously to the grove

- Scheduling fertigation is therefore complicated by the need to supply both water and nutrient requirements of citrus trees in the correct amounts during the growing season

- Optimally implemented fertigation reduces water and nutrient requirements and increases growth rates and yield of trees; all are desirable attributes in HLB-affected groves

- A Decision Support Program (DSP) was developed to help growers optimize their fertigation systems
Florida soils in agricultural production benefit from frequent additions of irrigation water and nutrients as fertigation.
Open hydroponics diminishes the role of soil and increases efficiencies

Typical agricultural soils

- Soil solution
- Readily available nutrient pool (CEC, fertilizer)
- Slowly available nutrient pool (e.g. OM-N, fixed P)
- Nutrient in soil minerals (e.g. mica, feldspar)

Florida’s sandy soils

- Low water-holding capacity
- Low CEC
- Low organic matter reserves
- Predominantly quartz

Open hydroponics with ACPS

- Daily drip fertigation

(Negligible dependence on soil – most efficient)
Lake Alfred: ‘Valencia’ @ 1.5 years 
drip fertigation: 2 drippers/tree
Dundee: ‘Vernia’ @ 2 years
drip fertigation: 18” spaced drip lines

8 x 18 feet = 303 trees/acre
Lake Placid: ‘Vernia’ @ 3 years
drip fertigation: 18” spaced drip lines
OR
Microsprinkler fertigation: 7.7 gph

47% HLB+ in March 2014
Auburndale: healthy ‘Hamlin’ yield in year 5:

Drip fertigation: 2 drippers/tree
OR
Microsprinkler fertigation: 10.5 gph
Common threads in these illustrated fertigation examples:

- Increased growth and early, high yields (Lake Placid is somewhat later)
- Increased water and nutrient use efficiency
- Minimal reliance on soil for water and nutrient storage = daily fertigation
Proper targeting of water and nutrients to the root zone ensures high efficiencies: drip emitters are ideal
Drip fertigation develops healthy, dense feeder roots
Properly designed microsprinkler irrigation systems can achieve similar high efficiencies: target the root zones of trees appropriate for their size. e.g. inverted emitters for young trees.
Upright microsprinkler emitters spray a water pattern that is too large for small trees; only a portion of the wetted zone is occupied by roots.
Inverted microsprinkler emitters spray a water pattern that more efficiently targets the root zone. When trees mature, the emitters are turned upright.
Wetted soil pattern: inverted emitter
Design of the DSP

- **Assumption:** With daily fertigation only enough water and nutrients are applied each day to match the needs of the trees (no storage in the soil necessary)

- Soil water content is maintained near field capacity, thus maximizing crop evapotranspiration and growth

- Irrigation requirements for trees of different sizes [ages] are calculated from average historical daily ET₀ and the proportional ground coverage by canopies

- Nutrient uptake patterns of citrus trees are inextricably related to transpiration patterns BUT the two are not necessarily dependent on each other at all times
Water movement

Transpiration (roots, xylem)

Evaporation (soil)
Transpiration is proportional to crop ET ($ET_c$) because $ET_c = T_c + E$

$ET_c$ for a grove acre is related to canopy size and its ground coverage
Data: 14 years of FAWN $ET_0$

Half sinusoidal curve (smooth repetitive seasonal oscillation)

Immokalee, FL
Data: 14 years of FAWN ET<sub>0</sub>

Sigmoidal curve: Seasonal nutrient demand is similar
66% of annual N fertilizer

Daily N requirements

Mid-season (June)
### Irrigation Zone Information

<table>
<thead>
<tr>
<th>Zone Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verna Dundee</td>
<td></td>
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<tr>
<td>Hamlin ACPS</td>
<td></td>
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<tr>
<td>10 gallon pots</td>
<td></td>
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<tr>
<td>Block 22 +Ca</td>
<td></td>
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<tr>
<td>Block 31 MS zone</td>
<td></td>
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<tr>
<td>Block 31 Drip zone</td>
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<tr>
<td>Gap drip</td>
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<tr>
<td>Gap MS</td>
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<tr>
<td>Block 22 -Ca</td>
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</tbody>
</table>

### Fertilization Information

- Annual N fertilizer (lb/acre): 175
- Fertilizer density (lb/gal): 10.2
- Fertilizer N% (w/w): 6
- Fertilizer TDS % (w/w): 22.4
- Injection pump rate (gph): 120
- Water EC (mS/cm): 0.5
- Final applied EC (mS/cm): 0.920
- Final applied TDS (ppm): 617
- N fert required (g/tree/day): 1.251
- N fert concentration (ppm): 92
- Fert amount (gal/day): 4.83
- Fert injection time (mins): 2.4
- Target N to date (lb/acre): 47

### Grove Irrigation Information

- Irrigation zone size (acres): 3.540
- In row: 8.0, between row: 18.0 (ft)
- Trees in the zone: 1073
- Trees per acre: 303.1
- Emitters/tree: 5.33
- Emitter flow (gph): 0.42
- Efficiency factor (%): 100.00
- Zone water flow (gpm): 40.0
- Average tree height (ft): 7
- Water required (gal/tree/day): 3.579
- Irrigation required (mins/day): 95.92

### Fertilization Pulsing

- Daily fertilization frequency (pulses/day): None
- Fertilization interval (days): 1
- Fert amount (gal/event): 4.825
- Irrigation required (mins/event): 95.92
DSP irrigation schedules are fine-tuned with soil water sensors.
Summary and Future Work

- A DSP based on ET₀ and canopy basal area coverage was developed to schedule daily fertigation for citrus trees of any size in a production season.

- Less frequent fertilizer injections (e.g. weekly) can be calculated by grouping consecutive daily amounts.

- A daily / weekly / monthly as-applied tracking database will be added to verify fertigation status and simplify “course-corrections.”
Summary and Future Work

- The DSP was developed with open-source programming software. Apple Mac-compatible versions can be compiled.
- In this first version, the irrigation schedules must be manually transferred to an irrigation controller.
- By request, the DRIS leaf diagnosis method will be added.
- A new fertigation controller (FC) is under development that will integrate the DSP into the integral functions of the controller. The controller will make and execute daily fertigation schedules automatically, including “course corrections”.
Summary and Future Work

- FC design: color touch screen embedded ARM computer with rugged enclosure; similar to our patented “CC Eye 8000 TreeSense®” used for variable rate agrochemical application
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