Observations on the water-use, water-use efficiency and total water footprint of a “cripps pink” apple orchard in the winter rainfall region of the Western Cape

Mark Gush – CSIR
Sebinasi Dzikiti – CSIR
Apple orchard water-use, efficiencies & footprint

Site selection

Ceres
Apple orchard water-use, efficiencies & footprint

- ‘Cripps Pink’ (‘Pink Lady’) on M793, Nooitgedacht Farm, Koue Bokkeveld
- 2.3ha, 13-yrs old (planted 1997), 5m tall, 1.25m X 4m (2000 spha), 60t/ha
- Automated Micro-spray fertigation system – short range Gyro’s
Automatic weather station for hourly measurements of rainfall, solar radiation, temperature, relative humidity, wind speed & wind direction (FAO56 Ref ET)

Reference Evapotranspiration - Ceres (mm)

- Apple orchard water-use, efficiency & footprint
- Automatic weather station for hourly measurements of rainfall, solar radiation, temperature, relative humidity, wind speed & wind direction (FAO56 Ref ET)
Apple orchard water-use, efficiencies & footprint

- Decagon probes for soil water measurements
- CS616 TDR probes for volumetric soil water content (top 10cm only)
- Irrometer and logger for timing of irrigation events
Apple orchard water-use, efficiencies & footprint

- Heat Pulse Velocity systems for continuous hourly sap flow (T) measurements
- Energy balance measurements to derive total evaporation (Eddy Covariance technique) – short-term seasonal monitoring
Apple orchard water-use, efficiencies & footprint

T & ET measurement

\[ R_n - G - H - LE = 0 \]

\[ LE (ET) = R_n - G - H \]
Apple orchard water-use, efficiencies & footprint

Use (mm.day⁻¹)

Daily Water-use (l.day⁻¹)

Annual T = 4 000 L / 825 mm (2008/2009)
Max = 42 L.day⁻¹

Sap flow results

© CSIR 2012 Slide 9
Apple orchard water-use, efficiencies & footprint

Annual T = 1 100 L / 281 mm (2008/2009)
Max = 15 L.day\(^{-1}\)
Apple orchard water-use, efficiencies & footprint

- End of season leaf senescence / drop
- Potential savings in irrigation volumes

**Diagram:**
- Water Applied (Irrigation plus effective rainfall) vs Water Used - 2008/2009
- Water Applied (Irrigation only) vs Water Used - 2008/2009

Accumulated Rainfall and/or Irrigation vs Water Applied and Water Used - 2008/2009

© CSIR 2012 Slide 11
Apple orchard water-use, efficiencies & footprint

• Use of 2-source model to simulate ET from trees & below canopy surfaces – calibrated & verified with observed data
Apple orchard water-use, efficiencies & footprint

**ET₀, ET & T results**

**Orchard Annual T = 700 mm, ET = 950 mm, ET₀ = 1580 mm**

Reference ET₀  |  Modelled ET  |  Measured T  |  Measured ET

Leaf Area Index

Month

© CSIR 2012  Slide 13
Crop coefficients

- 'Cripps' Pink apples
  - Ceres

Kc & Kcb - 'Cripps' Pink apples - Ceres

© CSIR 2012 Slide 14
Goal
- Improved understanding of water-use along the entire production chain of selected fruit tree species to assist in addressing the challenge of limited water resources by improving efficiencies and sustainability, with economic & environmental benefits.

Research Question
- Can we further develop Water Footprinting as a tool for water use assessment in South Africa, starting with the fruit tree industry—specifically apples & nectarines? What data, measurements and information is needed to accurately quantify footprints, and how can this best be used to improve water-use efficiency?

Focus
- Blue water footprint
  - volume of surface or groundwater evaporated, incorporated into product or transferred to another catchment or the sea.
Apple orchard water-use, efficiencies & footprint

<table>
<thead>
<tr>
<th>Orchard Evapotranspiration (ET)</th>
<th>Water footprint research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation from storage dam</td>
<td></td>
</tr>
<tr>
<td>Timber poles</td>
<td></td>
</tr>
<tr>
<td>Spraying Micronutrients</td>
<td></td>
</tr>
<tr>
<td>Spraying Fungicides</td>
<td></td>
</tr>
<tr>
<td>Spraying Pesticides</td>
<td></td>
</tr>
<tr>
<td>Spraying Herbicides</td>
<td></td>
</tr>
<tr>
<td>Chemical Fruit Thinning</td>
<td></td>
</tr>
<tr>
<td>Fruit Washing</td>
<td></td>
</tr>
<tr>
<td>Packhouse Water-use</td>
<td></td>
</tr>
<tr>
<td>Orchard Worker water use</td>
<td></td>
</tr>
<tr>
<td>Packhouse worker water-use</td>
<td></td>
</tr>
</tbody>
</table>

- Water footprint assessments / certification can address the challenge of increasing water stress by rewarding companies / farms for reducing water wastage and increasing water-use efficiency, leading to product preference, with economic & environmental benefits.
### Apple orchard water-use, efficiencies & footprint

<table>
<thead>
<tr>
<th>Water-use Component</th>
<th>Water volume (L/tree/yr)</th>
<th>%</th>
<th>Water volume (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transpiration</td>
<td>3414</td>
<td>683</td>
<td>683</td>
</tr>
<tr>
<td>Irrigation Applied</td>
<td>5070</td>
<td>1014</td>
<td>1014</td>
</tr>
<tr>
<td>Rainfall</td>
<td>5990</td>
<td>1198</td>
<td>1198</td>
</tr>
<tr>
<td>Orchard ET</td>
<td>4725</td>
<td>93.27%</td>
<td>945.0</td>
</tr>
<tr>
<td>Evaporation from storage dam</td>
<td>63</td>
<td>1.24%</td>
<td>12.6</td>
</tr>
<tr>
<td>Timber Poles</td>
<td>263</td>
<td>5.18%</td>
<td>29</td>
</tr>
<tr>
<td>Spraying Micronutrients</td>
<td>3.5</td>
<td>0.07%</td>
<td>0.7</td>
</tr>
<tr>
<td>Spraying Fungicides</td>
<td>3.0</td>
<td>0.06%</td>
<td>0.6</td>
</tr>
<tr>
<td>Spraying Pesticides</td>
<td>1.8</td>
<td>0.03%</td>
<td>0.4</td>
</tr>
<tr>
<td>Spraying Herbicides</td>
<td>1.3</td>
<td>0.02%</td>
<td>0.3</td>
</tr>
<tr>
<td>Chemical Fruit Thinning</td>
<td>2.0</td>
<td>0.04%</td>
<td>0.4</td>
</tr>
<tr>
<td>Fruit Washing</td>
<td>0.3</td>
<td>0.01%</td>
<td>0.1</td>
</tr>
<tr>
<td>Packhouse Water-use</td>
<td>2.7</td>
<td>0.05%</td>
<td>0.5</td>
</tr>
<tr>
<td>Orchard Worker water use</td>
<td>0.7</td>
<td>0.01%</td>
<td>0.1</td>
</tr>
<tr>
<td>Packhouse worker water-use</td>
<td>0.3</td>
<td>0.01%</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5066</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>990</strong></td>
</tr>
</tbody>
</table>
### Interim Results – Water Footprint linked to Yield / Production

<table>
<thead>
<tr>
<th></th>
<th>Apples (‘08/’09)</th>
<th>Apples (‘09/’10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield (Tons/ha)</strong></td>
<td>54</td>
<td>69</td>
</tr>
<tr>
<td><strong>Average Single Fruit Weight (g)</strong></td>
<td>160</td>
<td>158</td>
</tr>
<tr>
<td><strong>Trees per hectare</strong></td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td><strong>No. fruit per hectare</strong></td>
<td>337500</td>
<td>436709</td>
</tr>
<tr>
<td><strong>Fruit per tree</strong></td>
<td>169</td>
<td>218</td>
</tr>
<tr>
<td><strong>Total water-use per tree (L)</strong></td>
<td>5066</td>
<td>5172</td>
</tr>
<tr>
<td><strong>Water Footprint (L water/fruit)</strong></td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td><strong>Water Footprint (L water/kg fruit)</strong></td>
<td>188</td>
<td>152</td>
</tr>
</tbody>
</table>

- Year-to-year variation (dependent upon water-use & yield)
Apple orchard water-use, efficiencies & footprint

Water-use

• A 2000 spha 14 yr old ‘Cripps Pink’ apple orchard transpires:
  • ± 20-30 L water/day in summer (max 42 L)
  • ± 4000 L water/yr (Pollinator = ± 1100 L.yr⁻¹)
  • ± 4-6 mm water/day in summer
  • ± 680 mm/yr (6800 m³.ha⁻¹) (Pollinator = ± 2800 m³.ha⁻¹.yr⁻¹)
• However, orchard Total Evaporation = 950 mm/yr (9500 m³.ha⁻¹)

Water-use efficiency

• Use refined crop factors and FAO56 approach to plan irrigation
  • Potential late season irrigation savings – declining tree vigour
  / T
  • Transpiration (mm) ≠ Irrigation (mm) due to <100% IE
  • Option for pollinator-specific irrigation applications?

Water footprint

• Blue water footprint - 94% ET, 6% other. FSC-type certification?
  • Virtual water = ± 27 L water per apple (170 L/kg apples)
• Remember water-use of natural "baseline" vegetation
Acknowledgements

- Funding - Water Research Commission, DAFF & CSIR (PG)
- Project Team and students:
  - Seb Dzikiti, Vivek Naiken, Eric Prinsloo, Godfrey Moses (CSIR)
  - Nicky Taylor, John Annandale (Univ. Pta)
  - Alistair Clulow, Caren Jarmain, Michael Mengistu, Colin Everson

- Farmers & Farm Managers:
  - Louis Reynolds, Arno Marais (du Toit Agri)

Thank you!