Improving Pomegranate Fertigation and Water-Nitrogen Use Efficiency with Drip Irrigation Systems

Contributing Research and Support Staff

UC-KARE Center and USDA-ARS-SJVASC Staffs

Supports/Contributors
CDFA/Fertilizer Research and Education Program
Paramount Farming Company
LAKOS
TORO Irrigation
NETAFIM
SDI+
Verdegaal Brothers
2015 Research Objectives

To optimize water-nitrogen interactions to improve Water- and N-use efficiencies of Pomegranate and minimize N-leaching losses

a. Determine the effect of three rates of N-fertigation of pomegranate with High Frequency Drip Irrigation and Subsurface Drip Irrigation on N leaching losses.

b. Determine the seasonal N requirement of DI- and SDI-fertigated pomegranates which improves NUE without yield reduction.

c. Determine the seasonal water requirement of HF DI- and HF SDI-fertigated pomegranates which improves WUE without yield reduction.
IRRIGATION/FERTIGATION SYSTEMS

TORO Microirrigation, Drip In Classic with Rootguard,
0.620 in. diameter, 0.53 gph, 0.045-in. wall thickness, 18-in emitter spacing, Installed 3.5 ft. on each side of the tree row.

SDI laterals are installed at 20-22-in. depth.

Irrigation scheduling Fully automated, based on hourly ETc from lysimeter to apply same water volume as lysimeter (2.64 gal/tree/SDI irrigation and 2.84 gal/tree/DI irrigation).

Fertigation, N-P-K injected with irrigation water at rates to meet plant requirements, based on bi-weekly plant tissue analyses.
Experimental Layout

Randomized Complete Block Design with Subsamples

Irrigation Treatments
- Surface Drip (DI)
- Subsurface Drip (SDI)

Nitrogen Treatments
- 50% N1
- 100% N2
- 150% N3

Five Replications
- 3.54 acres
- 16 x 12 ft. tree spacing
BASIC SDI SYSTEM DESIGN

Diagram showing a basic SDI system design with various components labeled:
- Flushing manifold
- PVC mainline
- PVC riser
- Connector ring
- Vacuum relief valve
- Pressure relief
- Pressure gauge
- Emitters
- Flush valve
Installation of Subsurface Drip Irrigation (SDI) line at 20-22 in. depth

6 ft./1.8m lateral spacing
22 in./0.57m deep

Emitters: 0.53 gph
18 in./.47m spacing
Electro-Magnetic Flow Meters

N1
SDI  DI

N2
SDI  DI

N3
SDI  DI

To Lysimeter Refill Tank
Weighing lysimeter (4 x 2 x 2 m) resolution of 0.05 mm of evapotranspiration
DARCY’S LAW FOR UNSATURATED FLOW IN SOIL

THE RATE OF CHANGE OF SOIL WATER CONTENT

\[ \frac{\partial \theta}{\partial t} = - \nabla \cdot \left( K(\Psi) \nabla \Psi \right) + \frac{\partial K}{\partial Z} \]

CAPILLARY FORCE FIELD  GRAVITATIONAL FORCE FIELD
Darcy’s Law Implication

- Capillary force
- Gravitational force

Irrigation Scheduling of Drip Irrigation Systems Should Minimize the Flow Due the Gravitational Force Field (or avoid Saturation Drainage)
Patterns of Soil Water Distribution from a Subsurface Drip Point Source, as Affected by Irrigation Frequency and Soil Textures.
Desorption Curve For a Hanford Sandy Loam Soil
Crop Evapotranspiration, $E_{tc}$, Reference Evapotranspiration, $ET_o$ & Crop Coefficient, $k_c$

R.C. Phene
# Pomegranate Water Balance (in.)

<table>
<thead>
<tr>
<th>Year</th>
<th>$ET_o$ (in.)</th>
<th>Precip. (in.)</th>
<th>DI Irrig. (in.)</th>
<th>SDI Irrig. (in.)</th>
<th>$ET_c$ (in.)</th>
<th>Drainage (in.)</th>
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<tbody>
<tr>
<td>2010</td>
<td>49.73</td>
<td>17.34</td>
<td>1.0</td>
<td>1.0</td>
<td>2.1</td>
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<tr>
<td>2011</td>
<td>50.90</td>
<td>10.42</td>
<td>8.5</td>
<td>8.5</td>
<td>9.8</td>
<td>0</td>
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<tr>
<td>2012</td>
<td>54.60</td>
<td>8.97</td>
<td>18.6</td>
<td>17.7</td>
<td>19.7</td>
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<td>2013</td>
<td>55.00</td>
<td>3.21</td>
<td>25.4</td>
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<td>2014</td>
<td>57.80</td>
<td>8.62</td>
<td>33.4</td>
<td>30.7</td>
<td>35.9</td>
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<tr>
<td>2015**</td>
<td>49.61</td>
<td>3.52</td>
<td>34.76</td>
<td>31.46</td>
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</table>

2011 $ET_c$ values from 5/1 to 12/8 only.
*Lysimeter $ET_c$ adjusted for orchard spacing
**2015 Values are from January 1 to October 11th
Crop Evapotranspiration, $ET_c$
Reference Evapotranspiration, $ET_o$
Crop Coefficient, $k_c$

$ET_c = ET_o \times k_c$

The crop coefficient, $k_c$, is developed to relate $ET_o$ to the crop

CIMIS, California Irrigation Management Information System (www.cimis.water.ca.gov)
Crop Evapotranspiration, $ET_c$
Reference Evapotranspiration, $ET_o$
Crop Coefficient, $k_c$

The daily grass reference ET (CIMIS $ET_o$) and the orchard evapotranspiration ($ET_c$) measured hourly by the weighing lysimeter were used to develop irrigation requirement and crop coefficient for maturing pomegranate.
The graph illustrates the 2015 CIMIS ETo, Pomegranate ETc and Kc with the following equation:

\[ K_c = -0.00x^3 + 0.00x^2 + 0.00x + 0.01 \]

\[ R^2 = 0.87 \]
2014 Bi-monthly Pomegranate Kc

Crop Coefficient, Kc

<table>
<thead>
<tr>
<th>Date</th>
<th>Kc</th>
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<tr>
<td>1-Mar</td>
<td>0.19</td>
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<tr>
<td>1-Apr</td>
<td>0.30</td>
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<tr>
<td>1-May</td>
<td>0.40</td>
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<tr>
<td>1-Jun</td>
<td>0.48</td>
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<tr>
<td>1-Jul</td>
<td>0.55</td>
</tr>
<tr>
<td>1-Aug</td>
<td>0.61</td>
</tr>
<tr>
<td>1-Sep</td>
<td>0.67</td>
</tr>
<tr>
<td>1-Oct</td>
<td>0.72</td>
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<td></td>
<td>0.76</td>
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<tr>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>0.88</td>
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<tr>
<td></td>
<td>0.92</td>
</tr>
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<td>0.95</td>
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Soil Matric Potential & Hydraulic Gradient
C.J. Phene & R. Schoneman
Hourly SMP and Responses to 1.0 mm SDI Irrigation

1.0 mm irrigation
Irrigation/Fertigation Control System
2015 NITROGEN CONCENTRATION

- N-1 Conc. ppm
- N-2 Conc ppm
- N-3 Conc. ppm

<table>
<thead>
<tr>
<th>Time, Date</th>
<th>Leafing out</th>
<th>Flowering</th>
<th>Fruiting</th>
<th>Maturing</th>
<th>Harvest</th>
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<td>0</td>
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<tr>
<td>5/28</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>6/12</td>
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<td>7/12</td>
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<td>0</td>
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<tr>
<td>7/27</td>
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<td>0</td>
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</tr>
<tr>
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<td>8/26</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>9/10</td>
<td>0</td>
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<td>9/25</td>
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<td>0</td>
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Nitrogen Concentration, ppm
Total Nitrogen in Leaf Tissue (2015)

- %N values from 1.20 to 2.80
- Time points from 17-Mar to 13-Sep
- N1 DI, N2 DI, N3 DI
- N1 SDI, N2 SDI, N3 SDI
Total Nitrogen & Carbon in Leaf Tissue (2015)

% Nitrogen

% Carbon

- N1
- N2
- N3
Total Nitrogen in Fruit Parts (2014 harvest)

%N in Pomegranate Peels

<table>
<thead>
<tr>
<th></th>
<th>N1 DI</th>
<th>N1 SDI</th>
<th>N2 DI</th>
<th>N2 SDI</th>
<th>N3 DI</th>
<th>N3 SDI</th>
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<tbody>
<tr>
<td></td>
<td>0.72</td>
<td>0.73</td>
<td>0.97</td>
<td>0.91</td>
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<tr>
<td>N1</td>
<td>a</td>
<td></td>
<td>a</td>
<td></td>
<td>A</td>
<td></td>
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<tr>
<td></td>
<td>0.73</td>
<td>0.94</td>
<td>0.92</td>
<td>0.87</td>
<td>0.86</td>
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Note: a, b represent significant differences.
Total Nitrogen in Fruit Parts (2014 harvest)

%N in Pomegranate Arils

Total Carbon in Fruit:
No significant difference among treatments.
TC in peels 45% & arils 42.5%.
Soil Nitrate Profile (2014)

March

July

NO$_3$-N (mg/L)

Soil depth (in)
Soil Nitrate Profile (2014)

March

July

Soil depth (in)

NO$_3$-N (mg/L)

DI - SDI
Yields, WUE, NUE
<table>
<thead>
<tr>
<th></th>
<th>2014 Yields</th>
<th>Marketable Yield, lb/ac</th>
<th>Total Yield, lb/ac</th>
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<tbody>
<tr>
<td><strong>Irrigation Methods</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Surface Drip (DI)</td>
<td></td>
<td>28,909a</td>
<td>37,119a</td>
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<tr>
<td>Subsurface Drip (SDI)</td>
<td></td>
<td>33,442a</td>
<td>42,591a</td>
</tr>
<tr>
<td>Prob &gt; &quot;F&quot; value (5%)</td>
<td></td>
<td>NS</td>
<td>NS</td>
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<tr>
<td><strong>Nitrogen Levels (N)</strong></td>
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<td></td>
</tr>
<tr>
<td>(N-1) 35 lb N/ac</td>
<td></td>
<td>28,245a</td>
<td>40,344a</td>
</tr>
<tr>
<td>(N-2) 199 lb N/ac</td>
<td></td>
<td>30,532a</td>
<td>35,871a</td>
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<tr>
<td>(N-3) 305 lb N/ac</td>
<td></td>
<td>34,7494a</td>
<td>43,352a</td>
</tr>
<tr>
<td>Prob &gt; &quot;F&quot; value (5%)</td>
<td></td>
<td>NS</td>
<td>NS</td>
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</table>
Effects of irrigation and nitrogen treatments on WUE and NUE of pomegranate in 2014

<table>
<thead>
<tr>
<th>IRRIGATION TREATMENTS</th>
<th>WUE-PRIME</th>
<th>WUE-JUICE</th>
<th>NUE-N1</th>
<th>NUE-N2</th>
<th>NUE-N3</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>lb Fruit/ac-in</td>
<td>lb Fruit/lb N/ac</td>
<td></td>
<td></td>
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<tr>
<td>DI</td>
<td>865.5a</td>
<td>226.7a</td>
<td>1060.6a</td>
<td>186.5a</td>
<td>121.7a</td>
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<tr>
<td>SDI</td>
<td>1089.3b</td>
<td>285.3a</td>
<td>1216.9a</td>
<td>214.0b</td>
<td>139.6a</td>
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<tr>
<td>Prob &gt; F value</td>
<td>0.0086</td>
<td>NS</td>
<td>NS</td>
<td>0.0043</td>
<td>NS</td>
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Effects of Irrigation and Fertigation Treatments on Residual Weed Biomass

Weeds in DI vs NO weed in SDI
September 26, 2012
Following six years of intensive pomegranate irrigation and fertigation research with high frequency surface drip irrigation (DI) and subsurface drip irrigation (SDI), results have demonstrated that the high frequency SDI system has the potential to provide:

1. Higher and more durable system performance.
2. Minimize nitrate leaching by controlling the gravitational gradient.
3. More efficient water use efficiency (WUE) than DI.
4. Minimum potential for nitrate-nitrogen (N) leaching than DI.
5. Lower weed population and mass than DI.
6. Improved orchard cultural practices, development and production.
7. No significant differences in pomegranate fruit and juice quality.