Precise Irrigation for Olive Orchards

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Why Precision Irrigation?

Precision irrigation pursues to irrigate each tree with the due water amount, at the right time, and with the most adequate irrigation system.
How can Precision Irrigation be implemented?

Through the right choice of the...

Irrigation system

Irrigation strategy

Irrigation scheduling method

Full irrigation
Complementary irrigation
Sustained deficit irrigation
Regulated deficit irrigation
Is it feasible to apply PI in commercial orchards?
Is it feasible to apply PI in commercial orchards?

Irrigation

system

Irrigation

strategy

Irrigation

scheduling

Understanding olive adaptation to abiotic stresses as a tool to increase crop performance

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Regulated Deficit Irrigation for SHD olive orchards (45RDI)

\[ \text{IN} = \text{ET}_c - P_e \]

Irrigate to 100% IN if AW < 70% (daily).

- Irrigate to 80% IN if AW < 70% (daily).
- Irrigate to 20% IN (2 i.e./week).
- Irrigate to 15% IN if AW < 70% (1 i.e./week).

- Irrigate depending on rainfall (40% of IN).

\[ \text{IA} \approx 2000 \, \text{m}^3/\text{ha} \ (45\% \text{ of IN}) \]
\[ \text{IN} \approx 4400 \, \text{m}^3/\text{ha} \]

February: FRUIT DROP
March: CELL DIVISION IN THE FRUIT
April: MAXIMUM RATE OF PIT HARDENING
May: BLOOM
June: FLOWER INDUCTION
July: OIL ACCUM.
August: RIPENING
September: HARVEST for table
October: HARVEST for oil
November:

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Is it feasible to apply PI in commercial orchards?
Sap flow (SF) system

Olive trunk, Ø = 14 cm

Non functional xylem

Bark

V \Rightarrow V_c \Rightarrow Q \ (L/h) \Rightarrow \text{Water consumed}
Trunk diameter variations (TDV)

Holders made of Al and INVAR

Linear Variable Displacement Transducers = LVDT sensors
Leaf turgor pressure (TP): ZIM system
Plant-based methods to monitor water stress in the orchard

- The plant is used as a biosensor
- Continuous and automatic data recording
- They can be implemented with data transmission systems
Are these methods suitable to schedule irrigation?

Table 1
Requirements for a water stress indicator to be used in commercial orchards.

- The sensors are related equipment (the system) must be inexpensive and easy to install, operate and maintain.
- The system must be reliable and robust, capable of working under field conditions for the whole irrigation season.
- The system must allow for automated and continuous data collection and data transmission, with low power requirements (batteries fed with solar panels).
- The water stress index derived from the collected records must be highly sensitive, i.e. it must show a high signal:noise ratio.
- The derived index must also show an early response to the onset of water stress.
- The derived index must be related to a variable of economic importance, such as crop yield and fruit quality.
- The derived index, or the sensor outputs in case they are used without any further data processing, must be easy to interpret.
- If the index or outputs are not easy to interpret, the system must be provided with an application for visual readouts, graphs, historical records, and other tools to facilitate data interpretation.
- The system should be easily implemented with an application for the combined use of the chosen index with a weather prediction system. This will improve the user capacity for adjusting the timing and intensity of irrigation under changing weather conditions.
- The system should be easily combined with methods to define areas with characteristic water-stress behaviour within the orchard, such as remote imagery. This allows for precise irrigation in large, highly variable orchards.
- The index must be suitable for automatic irrigation scheduling and control. In this case, the system should be implemented with expert systems, alarms, and other tools for an early detection and lower impact of malfunctions.
How to overcome main limitations of TDV-, SF- and TP-related measurements to schedule irrigation?  

1. Cost

Plant-based systems to monitor water stress must be combined with remote imagery.
Remote imagery is now affordable for many orchardists

Photos by Geodim (www.geodim.es)

Photo by Dr. P. Zarco
Remote imagery is now affordable for many orchardists

- We can ‘see’ the variability within the orchard
- Combined with soil & crop maps, these images help to define areas of different sensitivity to water stress within the orchard

Each area can be instrumented&irrigated differently
How to overcome main limitations of TDV-, SF- and TP-related measurements to schedule irrigation?  

2. Data interpretation

The user can hire the services of specialized companies

www.Verdtech.es  
www.Phytech.com  
www.zim-plant-technology.com

User-friendly information can be send through the internet.
That information can be available to the user via PC, smartphone or tablet.
Research groups are developing increasingly “friendly” water stress indices.
Both technology and new knowledge are enough for PI to be a suitable option for commercial orchards

How to use it?

Impact on crop performance?
The early detection of water stress, plus the assessment of its importance from weather forecast, plus the irrigation “à la carte” highly increases the efficiency of irrigation management.

- Soil zones of different sensitivity to water stress are selected from remote imagery

- The onset of water stress in the most sensitive area is combined with 3-day weather forecast
Which is the impact of PI on crop performance?

Irrigation management depends on the production target

\[ WUE = \frac{\text{Dry matter (kg)}}{\text{Supplied water (m}^3)} \]

\[ WP = \frac{\text{Yield (kg)}}{\text{Supplied water (m}^3)} \]

\[ WP = \frac{\text{Net income (€)}}{\text{Supplied water (m}^3)} \]
Experimental orchard

Sanabria farm (Seville, south Spain)

Hedgerow orchard, cv. Arbequina, planted in 2007
4 m × 1.5 m (1667 trees/ha)

Experiments from 2010
(4 to 10 years old trees)

One lateral per tree row with one 2 L/h dripper every 0.5 m

Avg ET₀ = 1300 mm/yr
Avg rainfall = 500 "
The problem: how to manage irrigation in a SHD olive orchard

It is widely accepted that some 5000 m³/ha are required to fully irrigate hedgerow olive orchards with high plant densities (>1500 trees/ha).

But such amount is hardly available.

In addition, full irrigation could:

- Promote excessive growth
- Affect negatively oil quality
- Decrease water productivity (net income / m³ of water)

Production target: to achieve maximum profitability, i.e. to get the best balance between oil production and quality without reducing the orchard’s productive life.
After the three first experimental years (2010-2012), we found:

\[ \text{IN} = 4400 \text{ m}^3 \text{ ha}^{-1} \]

This applies to:

- Orchards with low WHC (49.5 mm)
- Trees with \( 8 < \text{LA (m}^2/\text{tree}) < 13 \)
  \( (\text{LA}_{\text{max}} \approx 22000 \text{ m}^2/\text{ha}) \)

<table>
<thead>
<tr>
<th>Month</th>
<th>( K_r )</th>
<th>( K_c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0.75</td>
<td>1.044</td>
</tr>
<tr>
<td>Feb</td>
<td>0.75</td>
<td>0.954</td>
</tr>
<tr>
<td>Mar</td>
<td>0.75</td>
<td>0.792</td>
</tr>
<tr>
<td>Apr</td>
<td>0.75</td>
<td>0.756</td>
</tr>
<tr>
<td>May</td>
<td>0.75</td>
<td>0.684</td>
</tr>
<tr>
<td>Jun</td>
<td>0.75</td>
<td>0.63</td>
</tr>
<tr>
<td>Jul</td>
<td>0.75</td>
<td>0.567</td>
</tr>
<tr>
<td>Aug</td>
<td>0.75</td>
<td>0.567</td>
</tr>
<tr>
<td>Sep</td>
<td>0.75</td>
<td>0.648</td>
</tr>
<tr>
<td>Oct</td>
<td>0.75</td>
<td>0.693</td>
</tr>
<tr>
<td>Nov</td>
<td>0.75</td>
<td>0.963</td>
</tr>
<tr>
<td>Dec</td>
<td>0.75</td>
<td>1.026</td>
</tr>
<tr>
<td>Irrigation Treatment</td>
<td>Irrigation amount (m³/ha)</td>
<td>Fruit yield (kg/ha)</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>FI 60RDI 30RDI</td>
<td>4.860</td>
<td>21.015</td>
</tr>
<tr>
<td></td>
<td>2.959 (61%)</td>
<td>14.415 (69%)</td>
</tr>
<tr>
<td></td>
<td>1.366 (28%)</td>
<td>11.715 (56%)</td>
</tr>
<tr>
<td>FI 45RDI$<em>{CC}$ 45RDI$</em>{TP}$</td>
<td>4.720</td>
<td>20.522</td>
</tr>
<tr>
<td></td>
<td>2.410 (51%)</td>
<td>14.490 (71%)</td>
</tr>
<tr>
<td></td>
<td>2.551 (54 %)</td>
<td>15.711 (77%)</td>
</tr>
</tbody>
</table>

2010 a 2012

2013 a 2015
Fruit quality parameters

- Fruits from the FI trees showed lower values of color index and higher values of ripeness than the RDI treatments.
- In general, irrigation decreased hardness.

Oil quality parameters

- Oils from all treatments showed values within the range for “Extra” VOO.
- The peroxide values showed differences among treatments, but inconsistent thorough the three seasons.
- The 30RDI oils had greater contents of carotenoids, chlorophylls and phenolic compounds, and showed a high oleic/linoleic ratio.
- The greater oxidative stability was shown by the 30RDI oils. No differences on this parameter were found between FI and 60RDI oils.
LA (m² tree⁻¹)

DOY

(For 2010 and 2011, DOY 150 = May 30; for 2012, DOY 150 = May 29)
Production target: to achieve maximum profitability, i.e. to get the best balance between oil production and quality without reducing the orchard productive life

With PI we achieve:

- 70% yield with 50% irrigation supply
- Better oil quality
- Lower pruning costs
- The productive life of the orchard is not threatened

Is PI, therefore, the best option?

We do not know yet (the good agronomic response has not been evaluated in terms of profitability): an economic analysis is required
Conclusions

- There is evidence on Precision Irrigation being the most suitable option for hedgerow olive orchards with high plant densities.

- Methods and tools for Precise Irrigation are available.

- An economic analysis for the orchard conditions is required to chose the best irrigation management, i.e. the most effective on achieving our production target.
Thank you

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