A preliminary evaluation of the leaf-patch-clamp-pressure probes (LPCPs) as online tools for irrigation scheduling in South Africa

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Approaches to irrigation scheduling

A. Atmospheric measurements and water balance techniques

- most common irrigation method

ETc = Kc . ETo (FAO 56)

B. Soil moisture monitoring

- tensiometers, capacitance probes,

-neutron probes etc

C. Plant-based monitoring

- ***contact sensors***

- pressure chambers/ psychrometers, dendrometers, leaf thickness sensors, sap flow, porometers etc

- ***non – contact sensors***

- infrared thermometers, aerial and satellite based

Dendrometers

Sap flow

Remote sensing based

Disadvantages of currently used plant-based irrigation scheduling tools

Pressure bomb

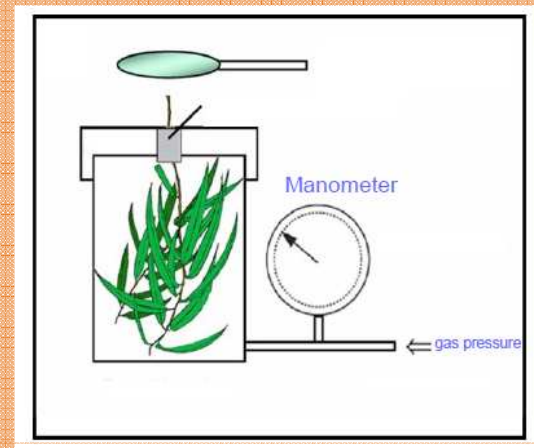
- utterly destructive
- labor intensive
- spot measurements

Sap flow

- sophisticated
- invasive
- can be unreliable

Dendrometry

- sophisticated
- invasive
- insensitive under drought conditions



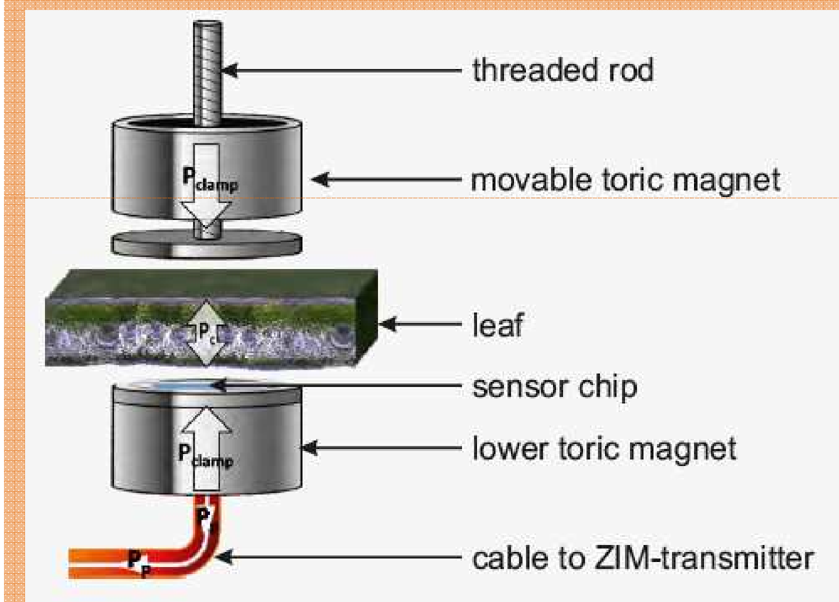
Leaf Patch Clamp Pressure probes (ZIM-probe)

- High precision probes that measure **leaf turgor pressure** non-invasively and in real-time
- Data can be accessed online (PCs, smartphone, tablets etc.)
- LPCPs have been evaluated on a range of crop types… but outside RSA

Probe operating principle

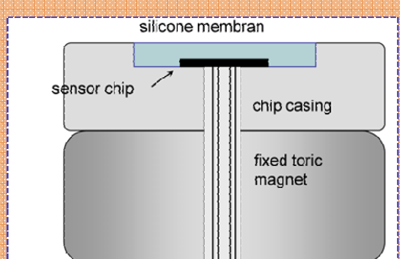
Turgor pressure (P_c) in the leaf patch is opposed to the externally applied constant **magnetic pressure** (P_{clamp})

ZIM-probe measures the difference (P_p) between the magnetic pressure and turgor pressure



$$P_p = \left(\frac{b}{aP_c + b} \right)^{\frac{1}{a}} \cdot F_a \cdot P_{clamp}$$

Zimmermann et al., 2008



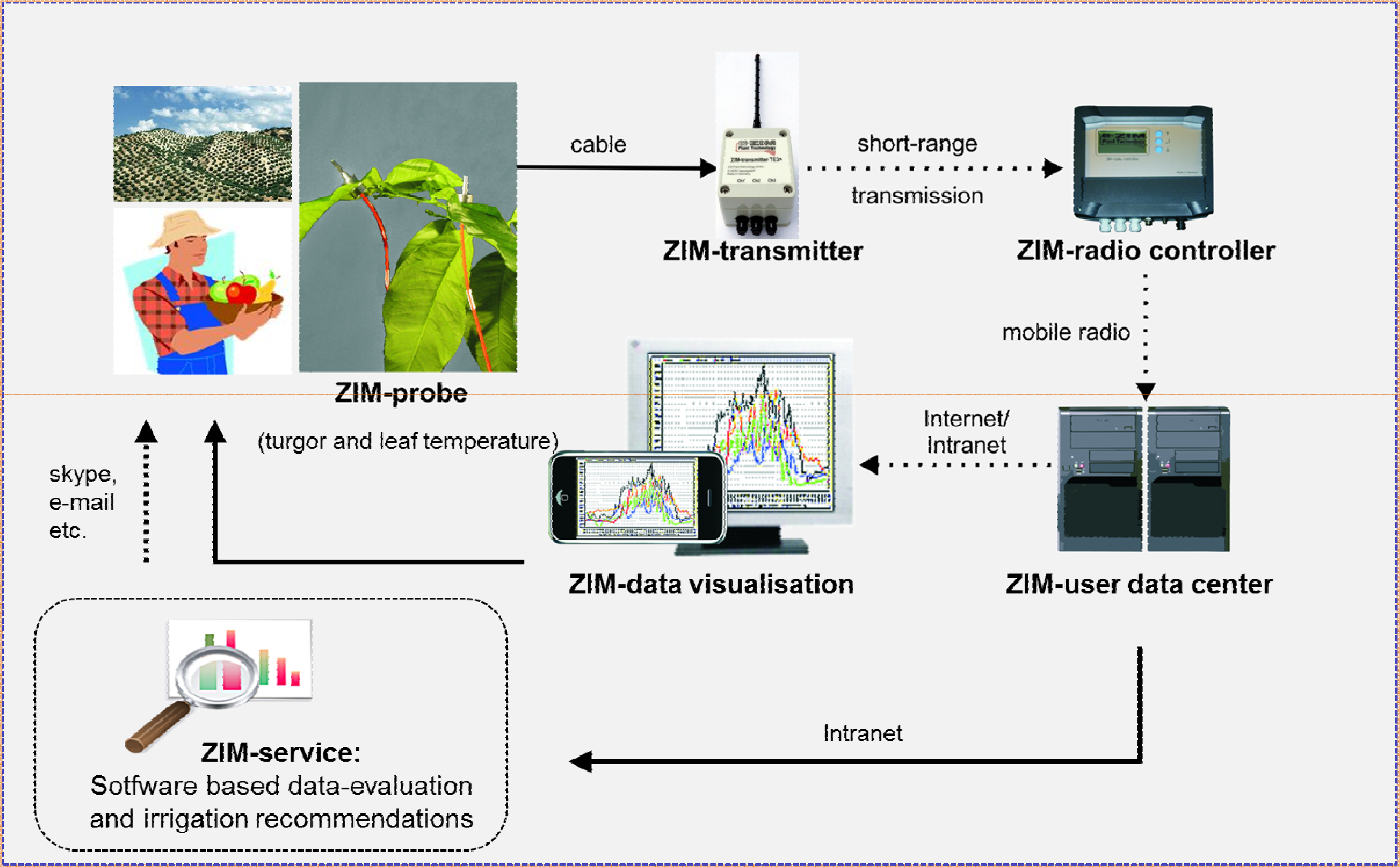
Specifications:

-Sensing area: Ø 4 mm;

-P_{clamp} : up to 370 kPa

P_p = patch pressure
P_c = turgor pressure
P_{clamp} = clamp pressure
F_a = attenuation factor (compression of cuticle, cell walls and air-filled interspaces)
a, b = elasticity constants

Measurement protocol



Aim: To evaluate ZIM-probes as online tools for irrigation scheduling in South Africa

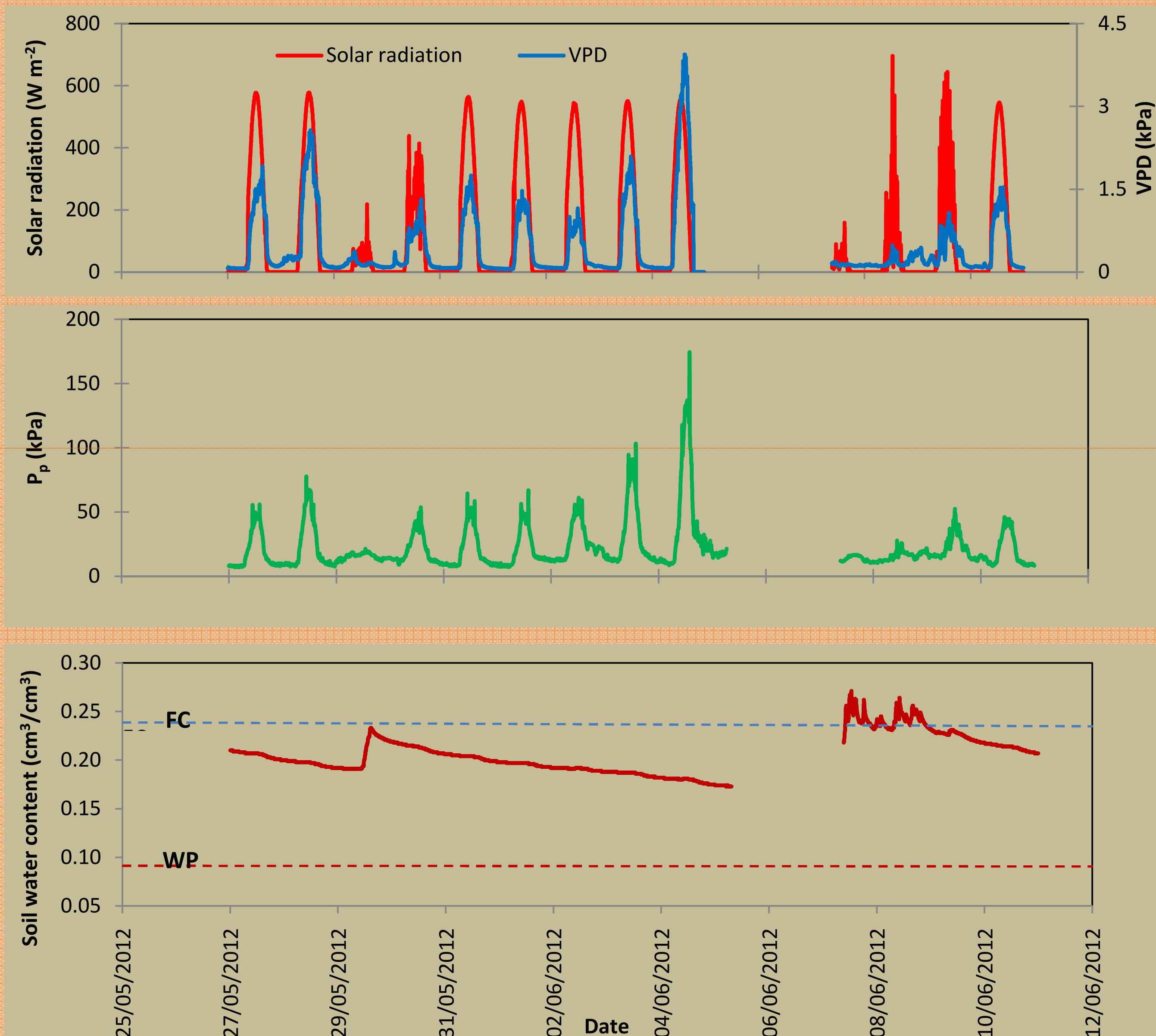
Tree water status: citrus

- -12 yr old Satsuma mandarin orchard at Stellenbosch University
- -Data collected from 15 May – 5 Sept 2012 @ 5 min intervals
- -R25 (30 MB) vodacom airtime – still running

Microclimate: Air temp, Relative Humidity, wind speed & solar radiation

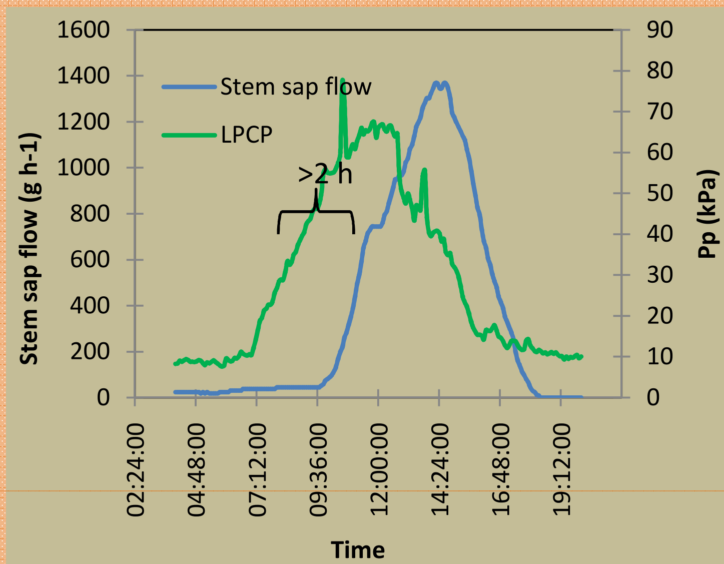
Sap flow and soil water content: Thermal dissipation probes and CS616 probes

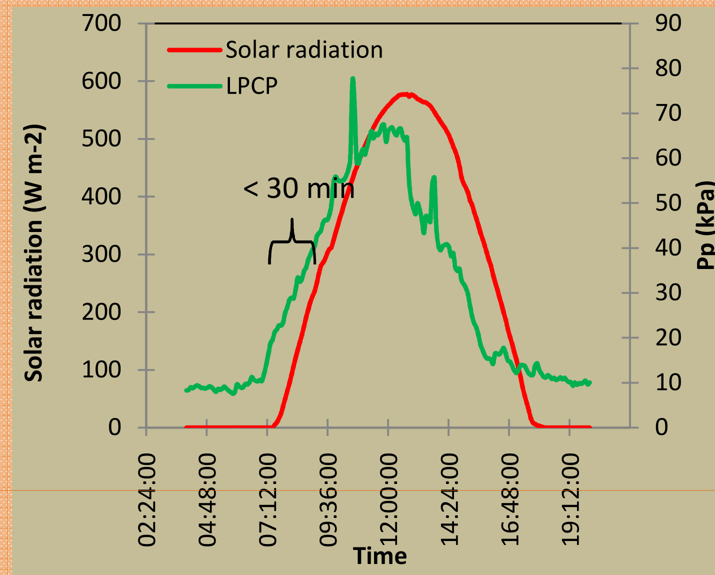
Response to environmental factors

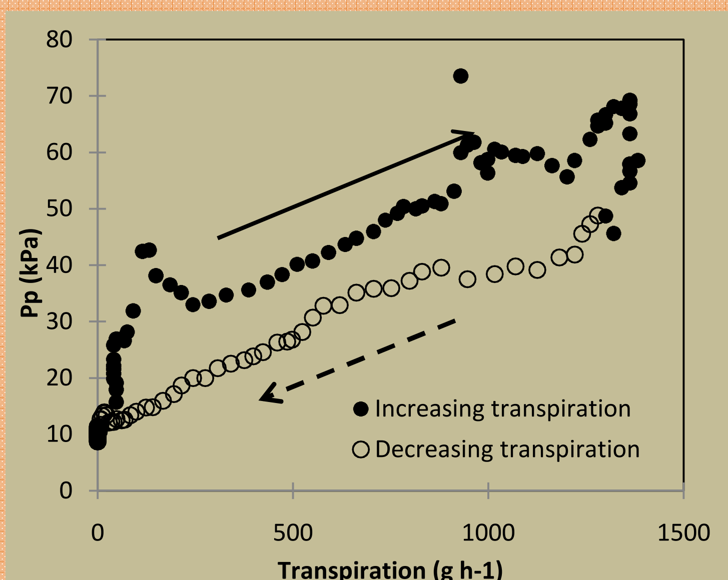


- **ZIM-probes** measure the integrated effects of the **microclimate** and the **soils** on the plant

ZIM-probe vs sap flow

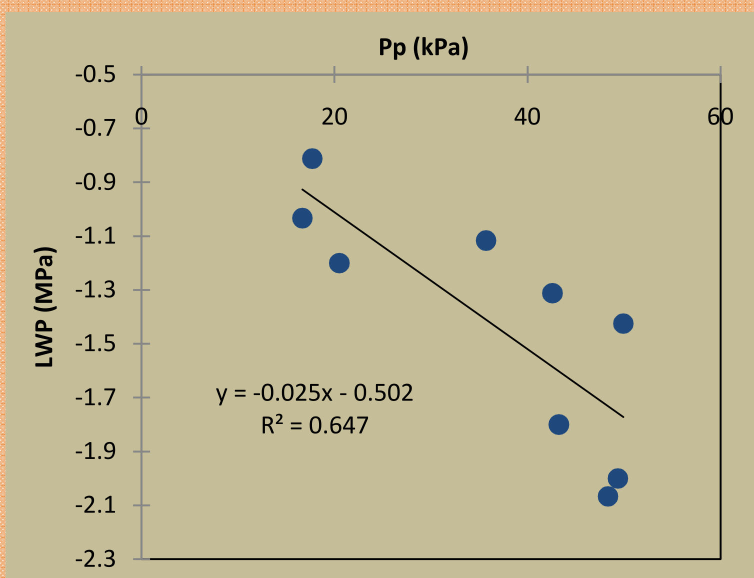






- Probe readings are dependent on the transpiration rates
- Significant hysteresis effect between ZIM-probe readings and the rising/ falling transpiration rates

Comparison of ZIM-probe measurments with pressure chamber readings

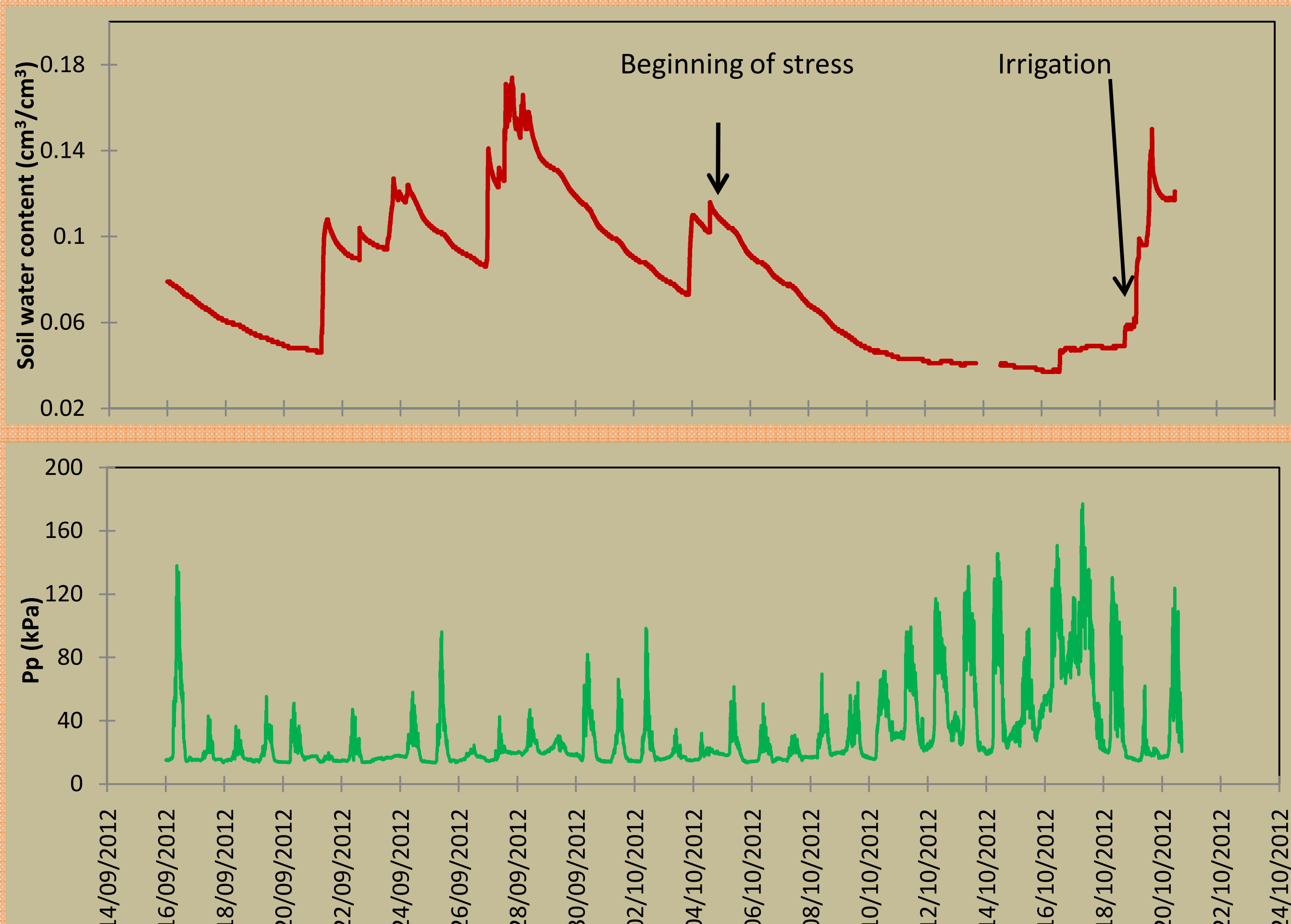


- midday leaf water potential for selected 9 days during the period May to September 2012
- there was a fairly linear relationship between the LWP and the average midday probe readings
- a stronger correlation with xylem water potential on nectarines (data not shown)
- range of stress values was narrow (in winter)

Potted citrus tree experiments (a larger stress range)

- Monitored the midday leaf water potential until severe stress had developed (< - 3.5 MPa)

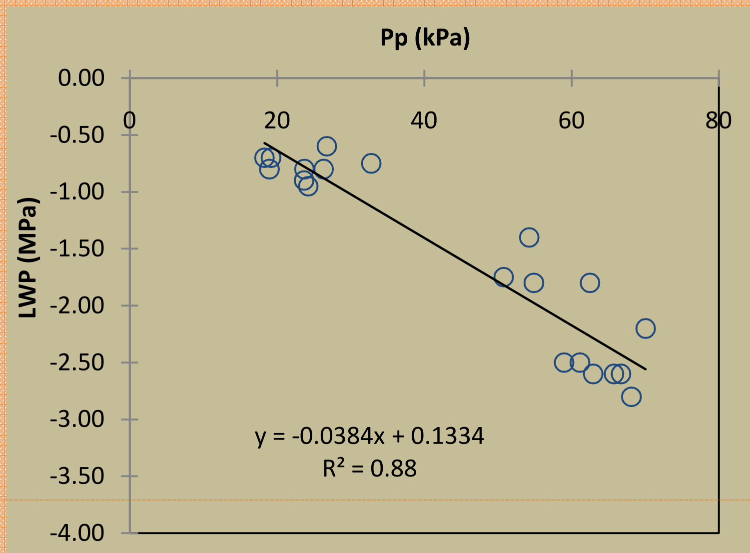
Response to severe soil drying



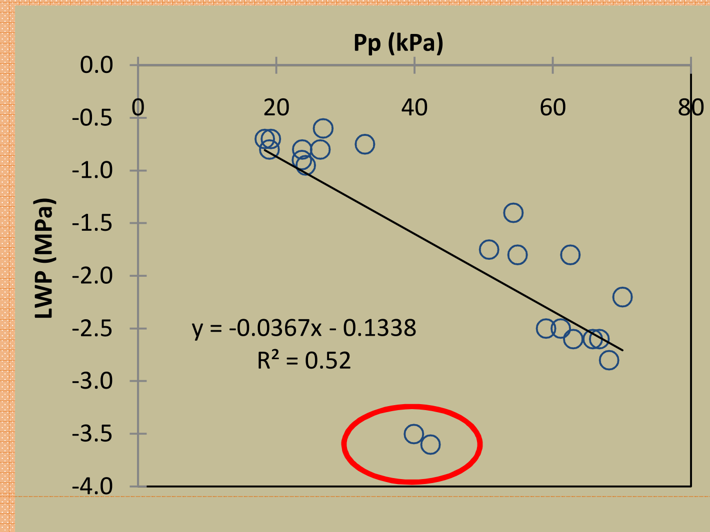
Leafless tree after re-watering

- Recovery of tree water status was incomplete under severe stress leading to higher night P_p-values
- tree lost almost all its leaves after re-watering and such stress levels are not expected in practice

ZIM-probe vs pressure chamber data for potted citrus



- Moderate stress data only



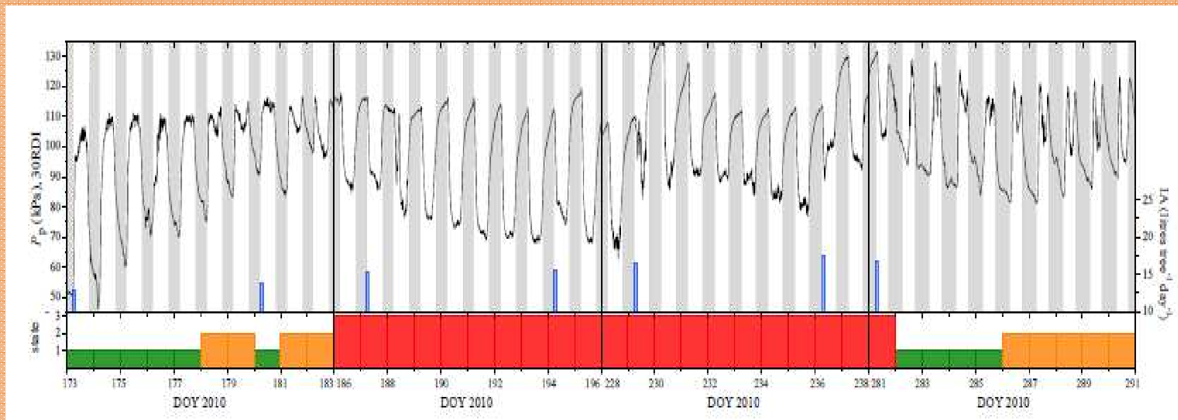
- Including severe stress levels < -3.5 MPa

Good linear correlation at moderate stress levels between the readings of the Scholander bomb and the ZIM probes

Poorer correlation with the midday leaf water potential at severe stress levels:

- Below *ca*. 50 kPa turgor pressure the attenuation factor Fa becomes the important and dominating parameter (air is accummulating in the leaf; beyond P_c=0 kPa the P_p values are meaningless. P_p reflects the temperature dependency of the entrapped air in the leaf)
- Scholander bomb values are increasing because excessive external pressure is needed to squeeze water out of the tissue

Inversion of P_p under severe water stress



= normal diurnal P_p -changes / no drought stress

= half-inversed diurnal P_p -changes / beginning drought stress

= inverted diurnal P_p -changes/ drought stress

- Data collected on olives under deficit irrigation by *Fernandez et al., 2011* in Spain
- Grey shades depict night time periods
- First panel shows P_p values when the trees were under progressive soil drying
- Next two middle panels shows Pp under severe stress and P_p-peaking occurred at night)
- Last panel shows the recovery of the trees after re-watering (day time peaks)

Changes in the curve shape can easily be detected and can therefore very easily be used for setting irrigation thresholds

Conclusions

Advantages

- LPCPs are quite sensitive to small changes in plant water status;
- Potential candidate for use in precision irrigation scheduling using state-of-the –art technology;
- Knowledge of soil moisture, microclimate and nutrients is not required if changes of turgor pressure of the leaves can be recorded non-invasively;
- Easy to install and use, and data transfer is cheap and reliable (where there is a good cellphone reception);
- Changes in the curve shape can easily be detected and can, therefore, used for setting irrigation thresholds.

Disadvantages

LPCPs do not give useful info about the plant water status at severe stresses (< - 3.5 MPa for citrus).

Thank you!!!