Assessment of several ground and remote sensing techniques for detection of plant water stress in woody perennial crops in south-east Spain

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The problem?

Assessment of plant water stress is a critical issue for optimizing irrigation scheduling. Stem water potential (ψ_{stem}), is the most common water status indicator in woody perennial crops but this cannot be easily automated and the number of measurements is limited.

The solution?

Thermography is a powerful tool to estimate crop temperatures and can be used as an indicator to evaluate water stress index in tree crops. Thermal images of plants can be taken in an individual way with thermographic handy cameras or collectively with a high spatial resolution multispectral camera on airborne platforms.

Materials and Methods

Experimental plots

Field measurements were conducted during 2009 in four experimental RDI plots located in Valencia (Spain), planted with Persimmon (*Diospyros kaki* L.f.), 'Clementina de Nules' (*Citrus clementina*, Hort ex Tan), Navel Lane Late (*Citrus sinensis* (L) Osbeck) and Pomegranate (*Punica granatum*). Each plot had a Control treatment, irrigated at 100% of ETc and several RDI treatments irrigated at 50 and 30-40% of ETc. pomegranate irrigation treatments are detailed in table1.

Individual thermal images of selected trees were taken in different days in persimmon and the citrus plots with an infrared thermal camera TH9100 WR (NEC San-ei Instruments), with 0.2 °C of precision and a spectral range of 8-14 µm (thermal image of 320x240 pixels and a visible image of 752x480 pixels). In the pomegranate plot, just one day were taken the thermal images with the handy camera but, furthermore, a multiband image was taken with a multispectral airborne camera (Leica ADS40) of 35 cm of spatial resolution and four bands (Red, Green, Blue and Near Infrared).

Multiband image analysis

Normalized Difference Vegetation (NDVI) index was calculated and values were extracted individually for each pomegranate tree (figure 3A).

Individual Thermal image analysis

Crop temperature (Tc) was calulated for each tree by means of an automated proccess analysis where vegetation was identified and by means of a mask average temperature of a vegetation area was computed (figure 3B)
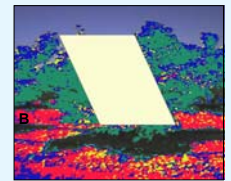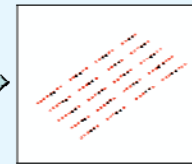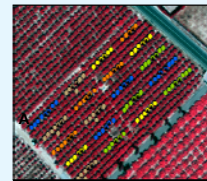
Figure 3 Extraction of individual tree NDVI values (A) Extraction of Tc (B)

Results

In pomegranate, trees from the most stressed treatment (figure1) had the lowest NDVI values (table1) while the control had the highest.

Treatment	NDVI
Control	0.470
RDI-1 (50% of ETc whole season)	0.420
RDI-2 (25% ETc May-Jun)	0.436
RDI-3 (25% ETc Jul-Aug)	0.463

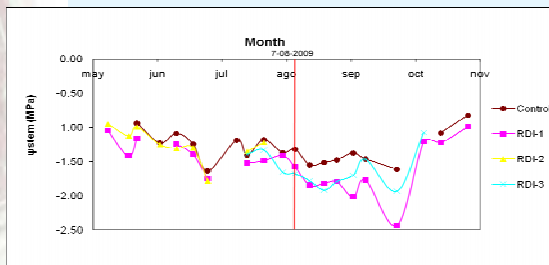**Table1.** Average NDVI value for each RDI pomegranate treatment.

Figure1. Evolution of ψ_{stem} in pomegranate during the whole season. The red vertical line shows the flight date (7-08-2009)

Figure 3. ψ_{stem} compared to NDVI (A) and Tc (B) in pomegranate the day 7-08-2009 .

• Persimmon trees showed a good relationship between Tc, ψ_{stem} and *gs* (table 2) in days with high differences of ψ_{stem}. In citrus trees there was poor relationship between Tc and ψ_{stem}.

Crop	DOY	R^2 (Tc-ψ_{stem}^{md})	R^2 (Tc-gs)	R^2 (gs-ψ_{stem}^{md})	ψ_{stem}^{md} (Mpa) Range	Tc (°C)Range
Persimmon	169	0.81	0.89	0.80	-1.2	9.0
	204	0.55	0.69	0.70	-1.3	9.7
	221	0.26	0.04	0.09	-0.7	2.3
	225	0.93	0.85	0.92	-1.5	8.7
	239	0.13	0.14	0.04	-0.4	4.6
	246	0.75	0.97	0.93	-0.9	3.7
	260	0.21	0.31	0.00	-0.2	5.6
	267	0.64	0.01	0.01	-0.3	4.1
Clementina de Nules	215	0.17	-	-	-0.4	3.8
	229	0.02	0.00	0.04	-0.8	5.1
	236	0.31	0.31	0.08	-0.9	3.1
	243	0.04	-	-	-1.3	4.5
	253	0.25	-	-	-1.4	3.7
Navel Lane Late	203	0.02	-	-	-0.5	3.7
	217	0.35	-	-	-1.1	4.0
	224	0.00	-	-	-0.7	3.1
	231	0.14	0.07	0.21	-1.2	3.2
	238	0.12	0.00	0.01	-1.4	2.0
	245	0.03	-	-	-1.1	3.9
	252	0.05	-	-	-1.1	4.3

Table2. R^2 for Tc- ψ_{stem}, Tc- gs, gs – ψ_{stem}, ψ_{stem} range and Tc range for each crop.

Conclusions

• NDVI seems to be a possible indicator for irrigation performing but not for scheduling.

• Thermal imagery can be used as an indicator to evaluate water stress index in tree crops depending on the crop.

Acknowledgements