Development of soil salinity in a grapevine orchard subject to controlled deficit irrigation

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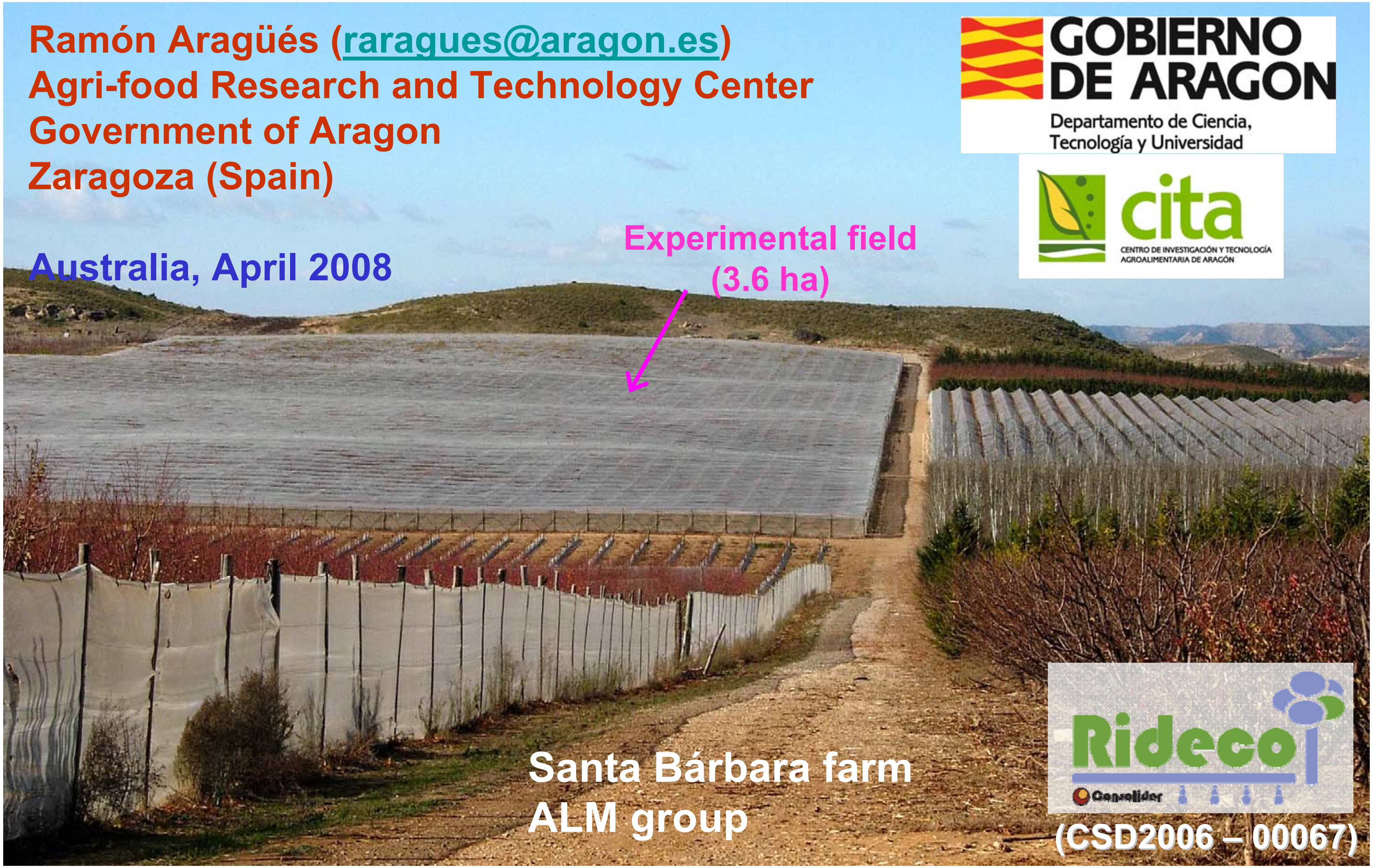

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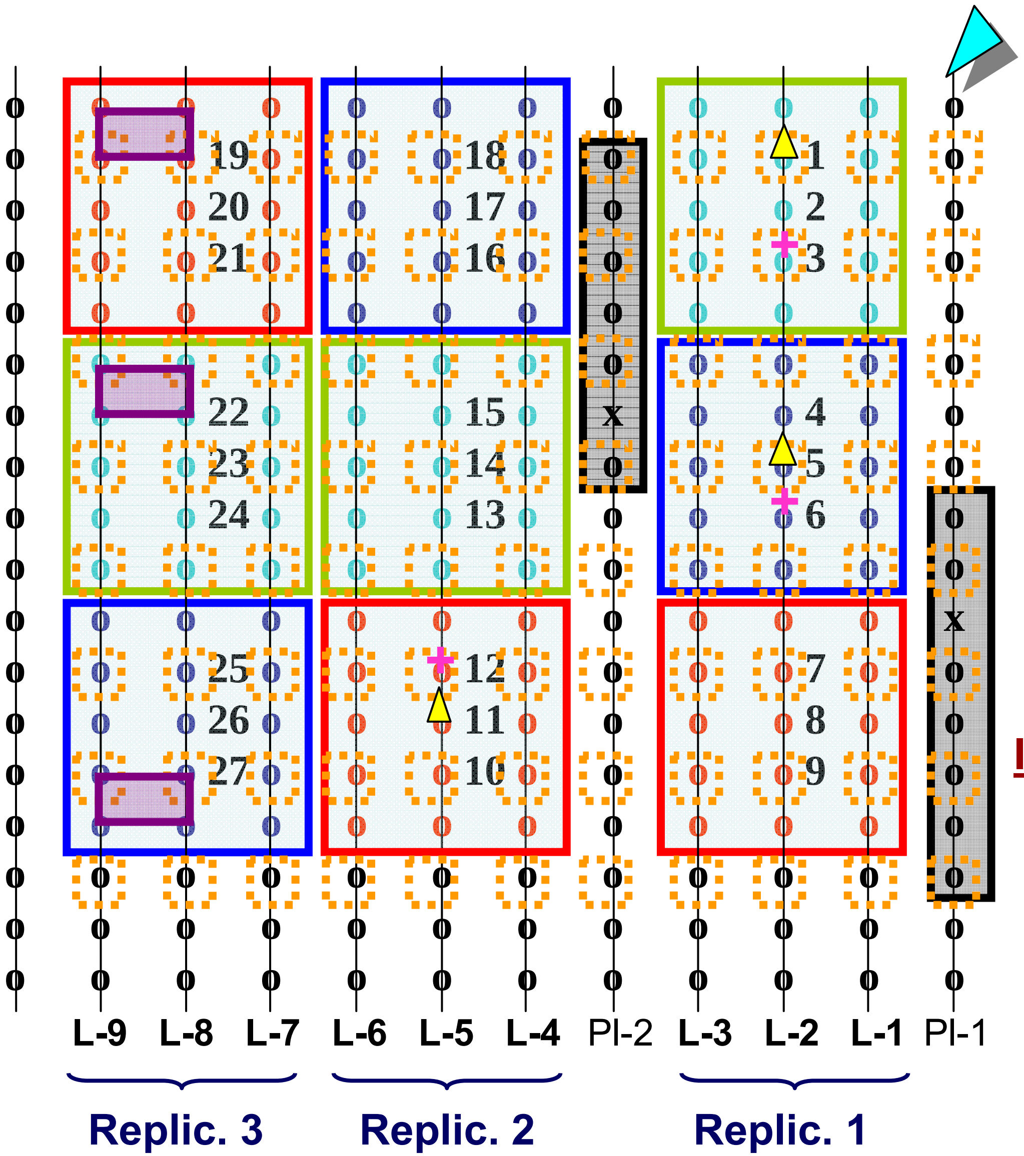
Rideco
Consolider
(CSD2006 – 00067)

Preliminary results
2007 irrigated season

Seedless table grapevines
Autumn & Crimson

Crimson- Experimental setup 2007



o Vines (3.5 m. x 2.5 m.)
1-27: control vines for growth

Sampling of irrigation water

Soil mulching with black plastic

Hydraprobes and suction cups in C-1, C-5 and C-11

\+ Soil sampling in C-3, C-6 and C-12

EM sensor readings (horizontal)

EM sensor readings in-between lines

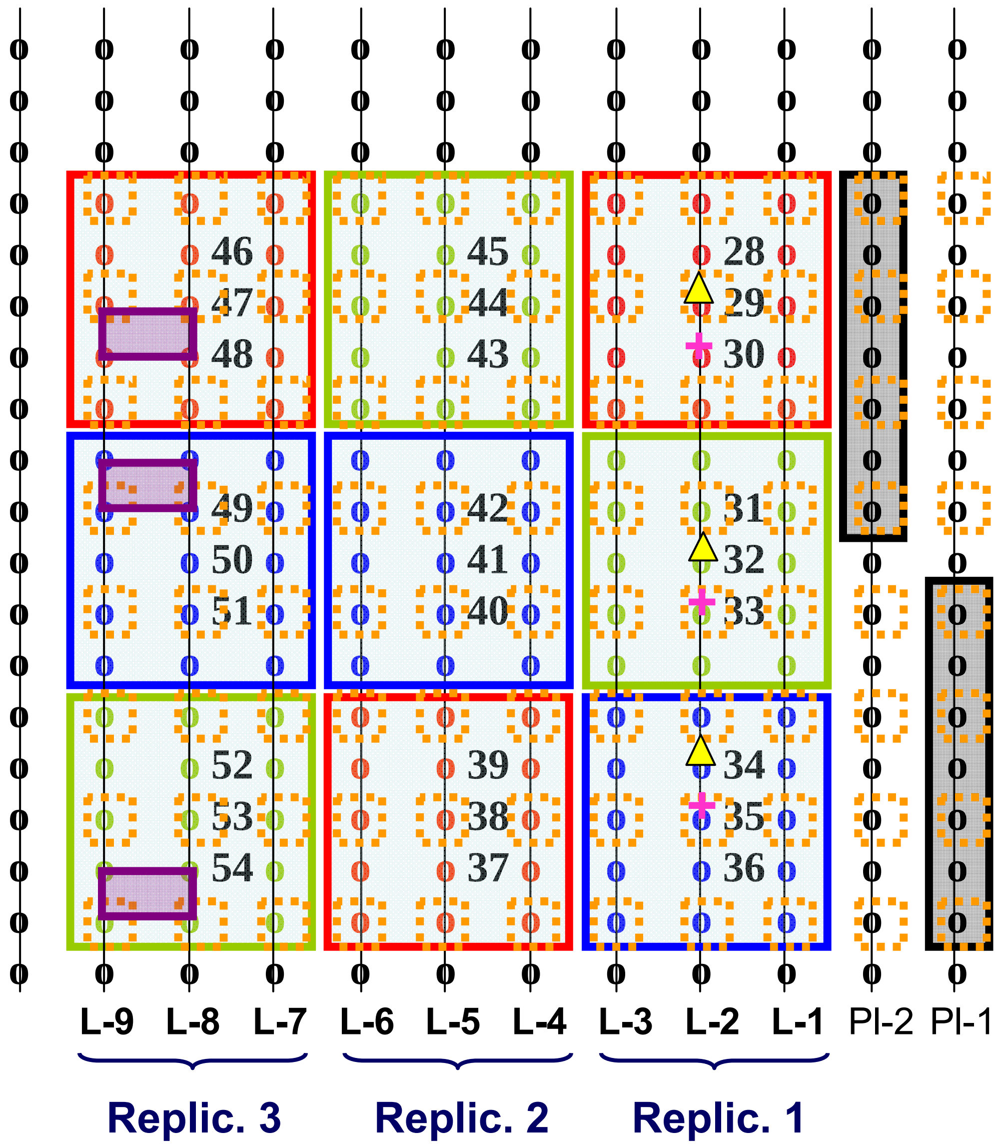
Irrigation treatments (February-September)
(CDI from veraison to harvesting)

T1 (100% ETc) (I = 711 + P = 237; Total = 948 mm)

T2 (80% ETc) (I = 640 + P = 237; Total = 877 mm)

T3 (60% ETc) (I = 566 + P = 237; Total = 803 mm)

Autumn Royal- Experimental setup 2007



o Vines (3.5 m. x 2.5 m.)
28-54: control vines for growth

Soil mulching with black plastic

Hydraprobes and suction cups in A-29, A-32 and A-34

+ Soil sampling in A-30, A33 and A35

EM sensor readings (horizontal)

EM sensor readings in-between lines

Irrigation treatments (February-September)
(CDI from veraison to harvesting)

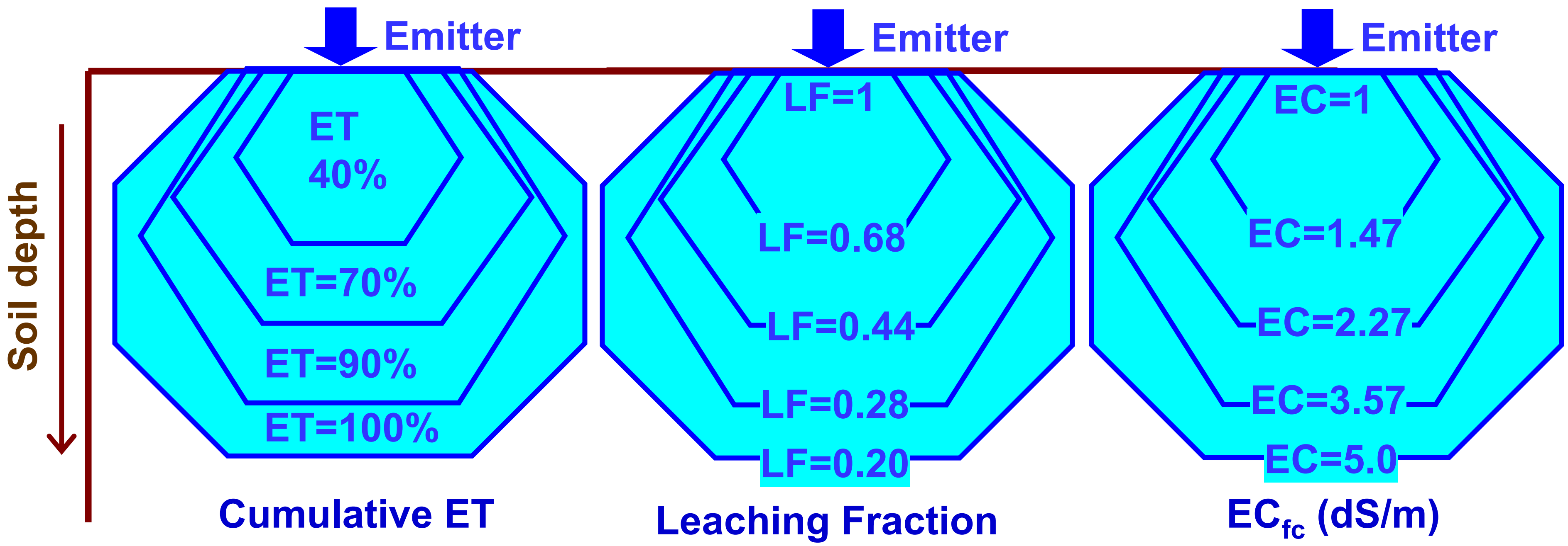
T1 (100% ETc) (I = 711 + P = 237; Total = 948 mm)

T2 (80% ETc) (I = 640 + P = 237; Total = 877 mm)

T3 (60% ETc) (I = 566 + P = 237; Total = 803 mm)

- **Drip irrigation (three-dimensional flow)**
    - Cumulative ET increases with distance from emitter ⇒
    - LF decreases with distance from emitter ⇒
    - EC increases with distance from emitter

Estimated field capacity EC_{fc} values
(example for EC irrigation water = 1 dS/m and LF = 0.2)



It is assumed (¿?) that crops respond to EC_{fc} weighted-averaged by crop's extraction rate = 2.1 dS/m

- **Typically, irrigation frequency in drip irrigation is high (daily).**

- **Although for a given LF, evapo-concentration will be similar to that of other irrigation systems, the high frequency leaches the salts towards the edge of the wetted bulb. Thus, leaching is also needed in drip irrigation...**

- **The classical concept of leaching requirement (LR) is not applicable in drip irrigation because crops tend to extract the lower saline soil solution, close to the emitter.**

- **Leaching with extra irrigation water is needed on a yearly basis in areas with insufficient rainfall.**

- **Soil salinity is highly variable in drip irrigation.**

- **How and where should monitoring be performed to obtain salinity values representative of those to which crops are exposed?**

- **Quantification of actual ET is critical to know the spatial and temporal variability of soil salinity due to evapo-concentration. Major constraint in modeling efforts...**

- **Location of emitters is very important because it is the source of water for leaching of salts. This is not taken into account in many commercial farms...**

Controlled Deficit Irrigation (CDI)

- **CDI is a strategy that reduces the volume of irrigation. It is also advocated that the quality of harvest (like in grapevines) may increase.**
- **During the CDI periods, LF is low or zero and, therefore, soil salinity may increase. This strategy may be unsustainable when irrigating with medium to high salinity waters.**
- **Hypothesis: crops tend to extract the soil solution of lowest salinity.**
- **Approach: measurement of low to medium salinity within the wetted bulb.**
- **This presentation is focused on methodologies for measuring soil salinity in drip irrigation...**

Selected methods for soil salinity monitoring in a CDI trial in table grapevine (Caspe, Zaragoza, Spain).

1- Continuous recording of apparent electrical conductivity (ECa) and volumetric soil water content (θ) with Hydraprobe II sensors.

2- Frequent extraction of soil solution with ceramic suction cups and measurement of ECss.

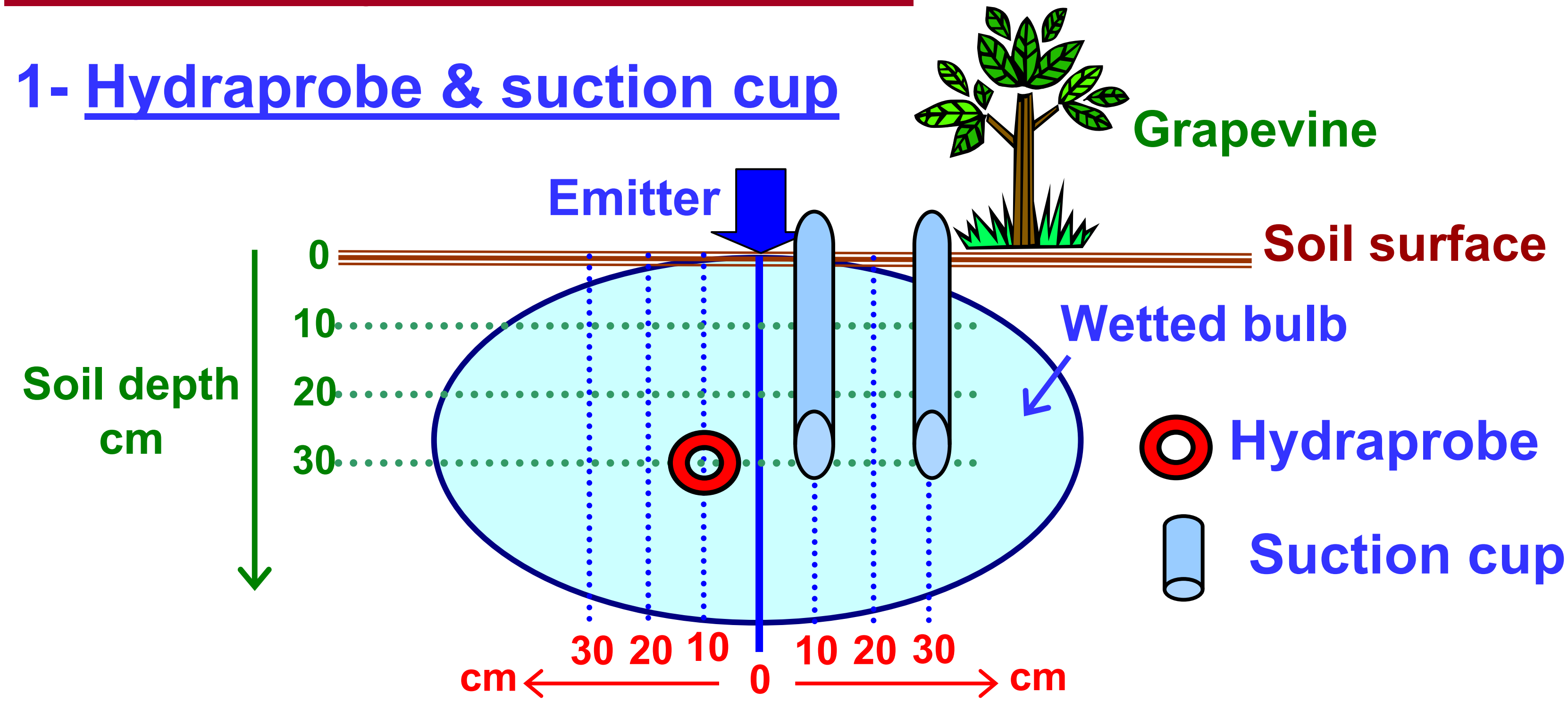
3- Measurement of saturation extract ECe in soil samples taken at the beginning / middle /end of irrigated season.

4- Measurement of horizontal ECa with Geonics EM38 in all vines included in the trial.

5- Measurement of horizontal and vertical ECa with Geonics EM38 in-between grapevine rows (i.e. measurement of ECa of natural soil, not altered by irrigation).

Soil salinity measurements

1- Hydraprobe & suction cup



- Hydraprobe (ECa, θ): one installed in each treatment (T1, T2, T3); 2 varieties x 3 treat. = 6 sensors
- Ceramic suction cup (ECss): two installed in each treatment (T1, T2, T3); 2 varieties x 2 cups x 3 treat. = 12 cups

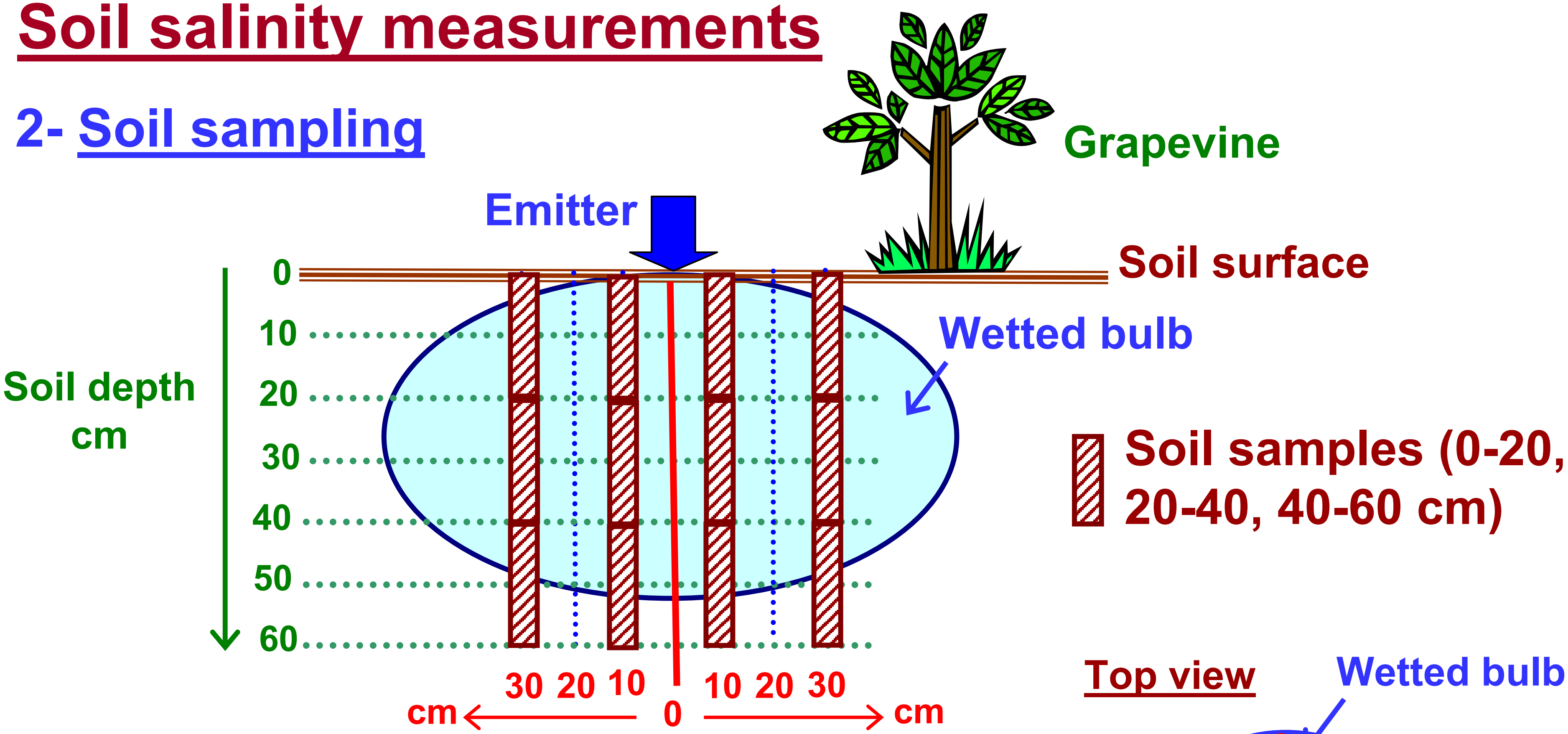
Ceramic suction cup (homemade; 15 €)

Hydraprobe (400 €/unit)

Stevens patented Hydra Probe design is unique compared to other soil moisture probes because the electrical response of soils can be specified by two parameters, the dielectric constant and the conductivity. The dielectric constant is most indicative of water content while the conductivity is strongly dependent on soil salinity. Unlike other capacitance type sensors, the Hydra Probe measures both of these components simultaneously. The high frequency electrical measurements indicating the capacitive and conductive properties of soil are then directly related to the soil's moisture and salinity content while a thermistor determines soil temperature. These unique sensors feature all three simultaneous readings for more definitive analysis of soil conditions.

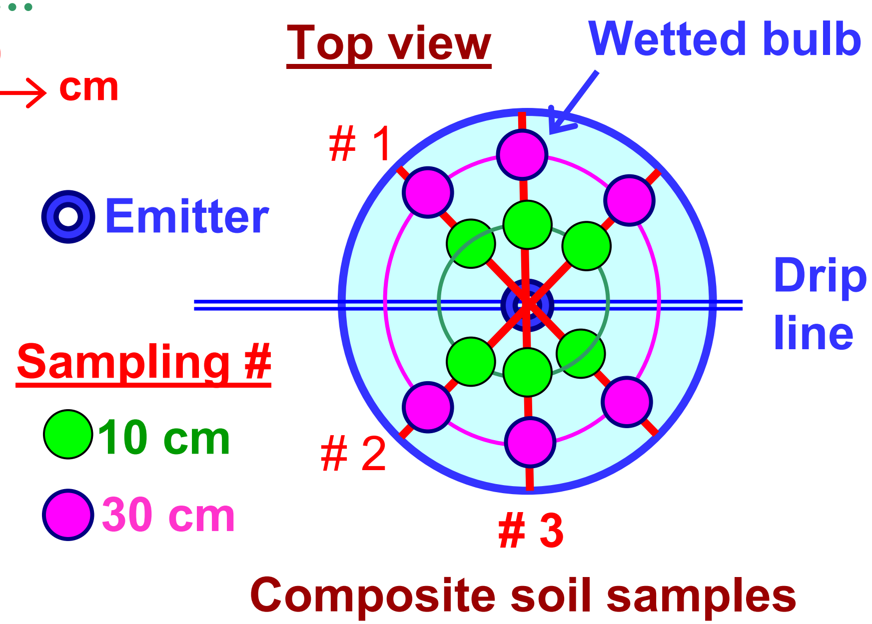
Soil salinity measurements

2- Soil sampling



-Soil samples (ECe & ions): initial, middle (just before start of CDI) and final samplings in each treatment (T1, T2, T3) at 0-20, 20-40 and 40-60 cm depths.

-2 var. x 3 treat. x 2 distances from emitter x 3 sampling dates x 3 soil depths = 108 soil samples.



Soil salinity measurements

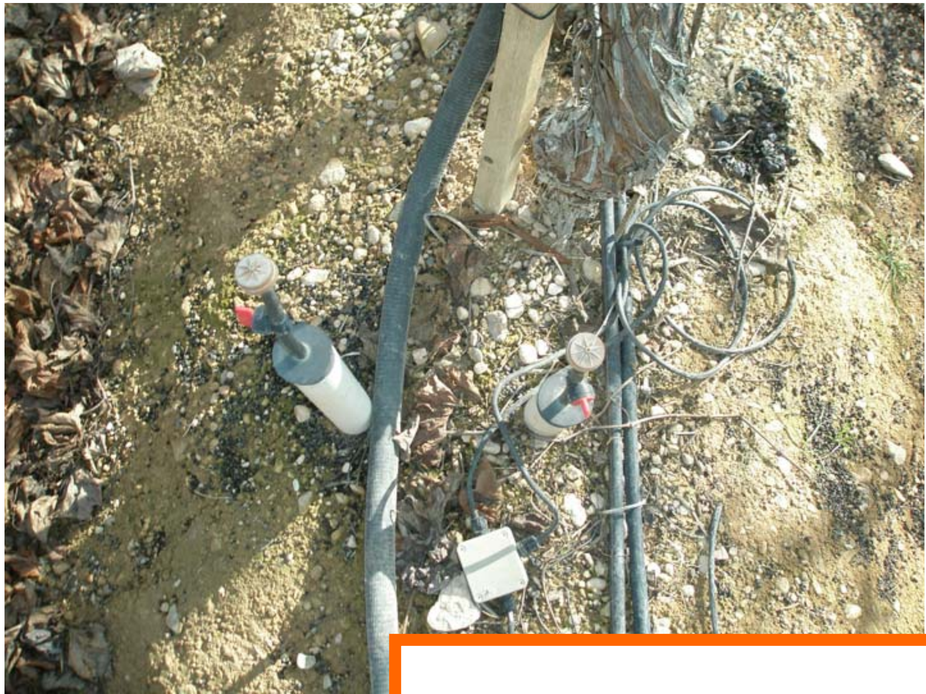
3- EM sensor (Geonics EM38)

a) Measurement of horizontal ECa (Geonics) close to each vine (fortnightly)

Variety	Nº dates	Total lectures
Autumn Crimson	5	5 dates x 3 treat. x 3 rep. x 2 var. x 8 vines/var. = 720

b) Measurement of horizontal & vertical ECa in-between lines, parallel to the lines

Variety	Nº dates	Total lectures
Autumn Crimson	2	2 dates x 3 treat. x 2 var. x 20 positions = 240

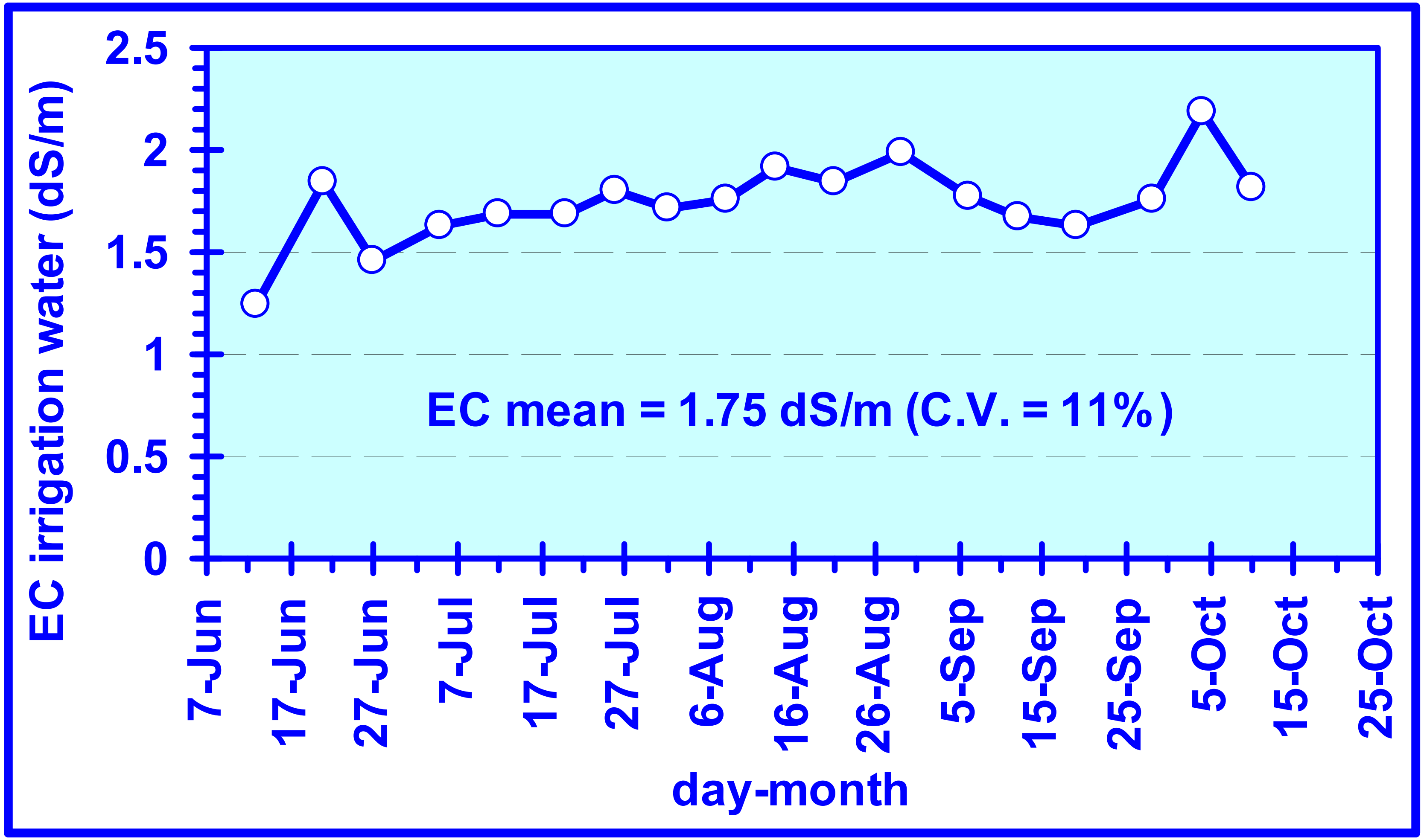


2007- Summary of results

AUTUMN ROYAL

CRIMSON

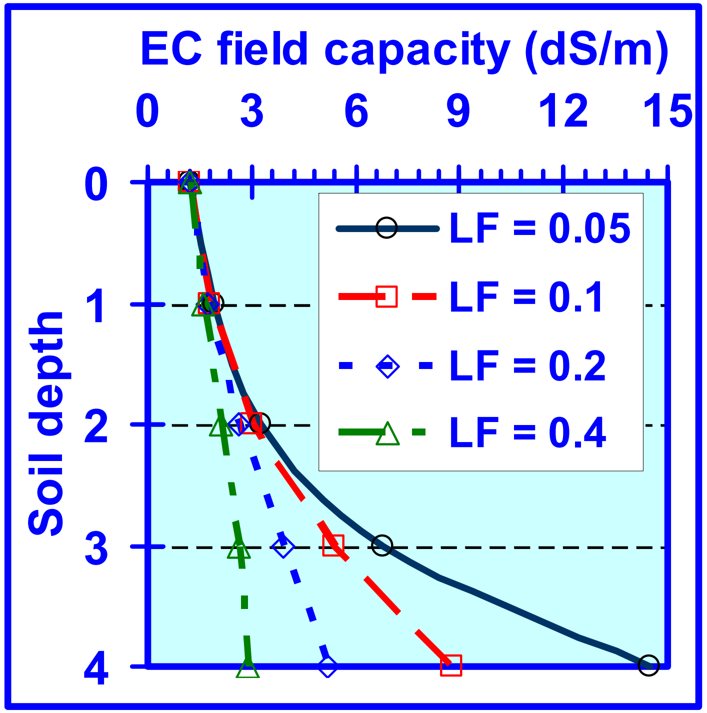
EC irrigation water



According to FAO conventional nomogram, this water is suitable for grapevine irrigation

Watsuit application. Field capacity EC and SAR values (average and upper root zone) for different leaching fractions

Irrigation water (meq/l)							
Na	Ca	Mg	K	Cl	SO_4	HCO_3	CO_3
3.8	7.2	4.0	0.3	5.4	7.3	3.9	0.0



ECe ≈ 0.5 ECfc

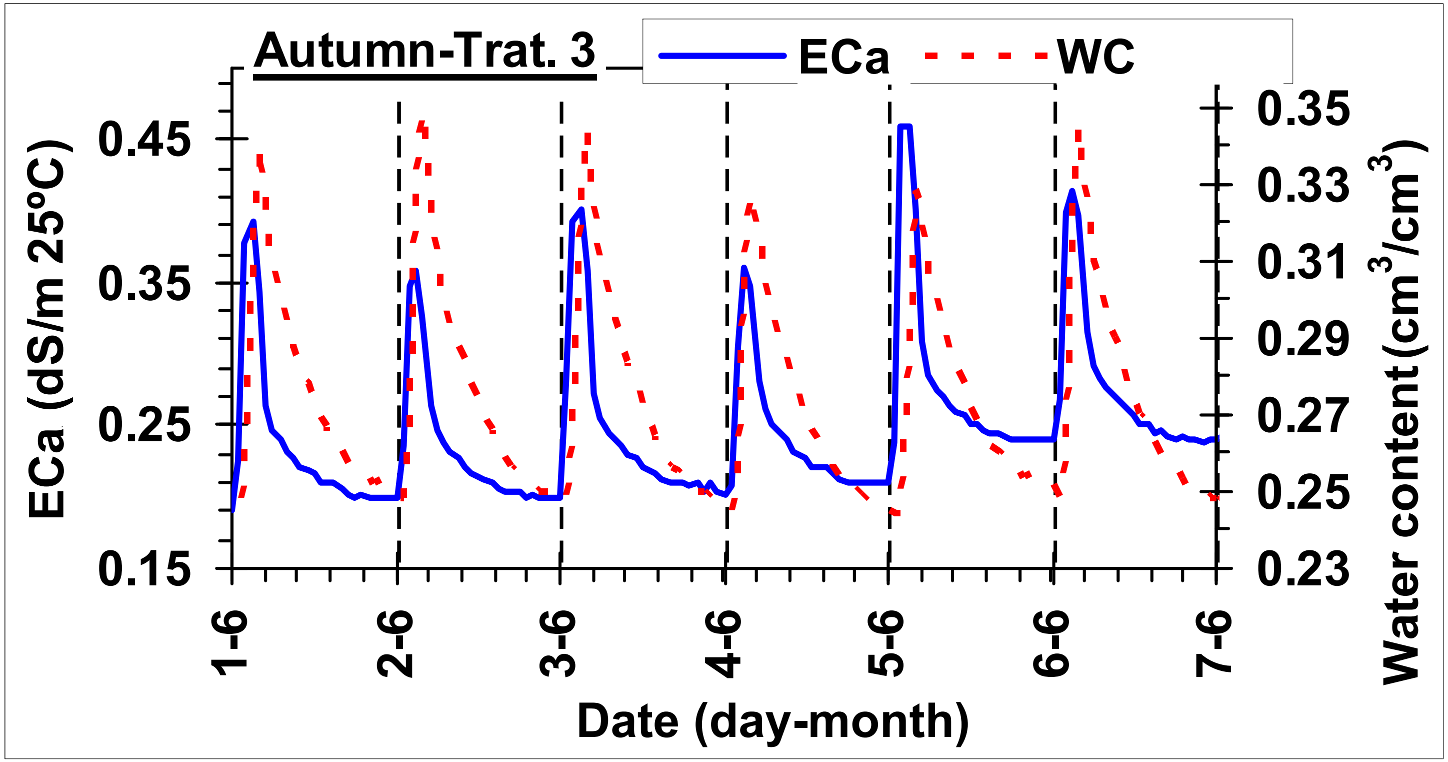
	LF			
	0.05	0.1	0.2	0.4
ECfc				
Mean	5.0	3.8	2.8	2.1
Upper	2.1	2.0	1.8	1.6
SARfc				
Mean	4.1	3.4	2.8	2.2
Upper	2.3	2.3	2.2	2.0

Grapevine threshold ECe (90% yield) = 2.5 dS/m

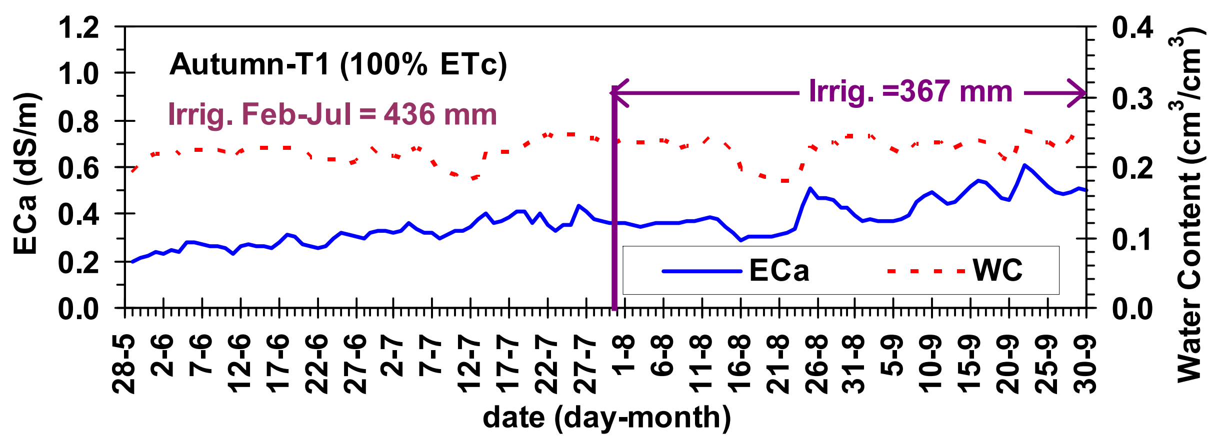
Do to calcite (and gypsum) precipitation, Watsuit predicts lower EC than conventional Nomogram.

Water suitable for grapevine irrigation

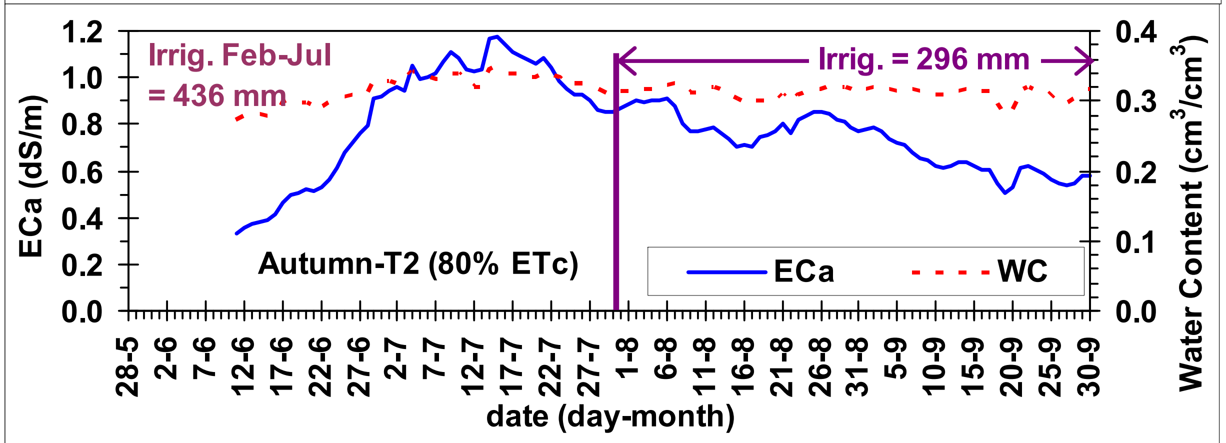
- **Hydraprobe II (ECa and θ every 10 min)**
- **Good functioning.**
- **Reflects properly the daily nocturnal irrigations (sharp θ increase).**
- **But ECa also increases with irrigation, when it should decrease if only affected by salinity ($EC_{iw} < EC_{soil\ solution}$)**



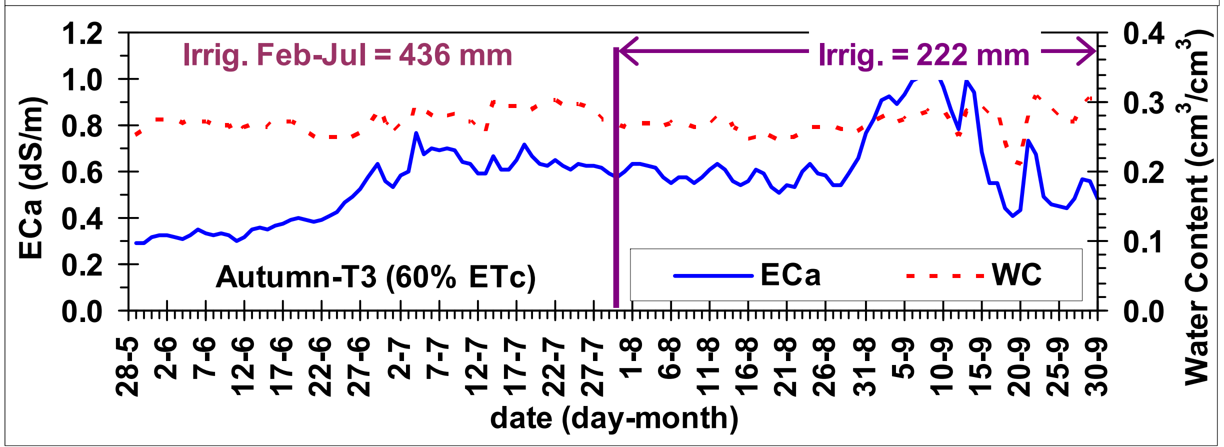
• Hydraprobe II: ECa and θ in Autumn



T1	ECa	θ
Mean	0.37	0.22
St. D.	0.09	0.02
CV (%)	24	8
Mean Aug-Se	0.42	0.23

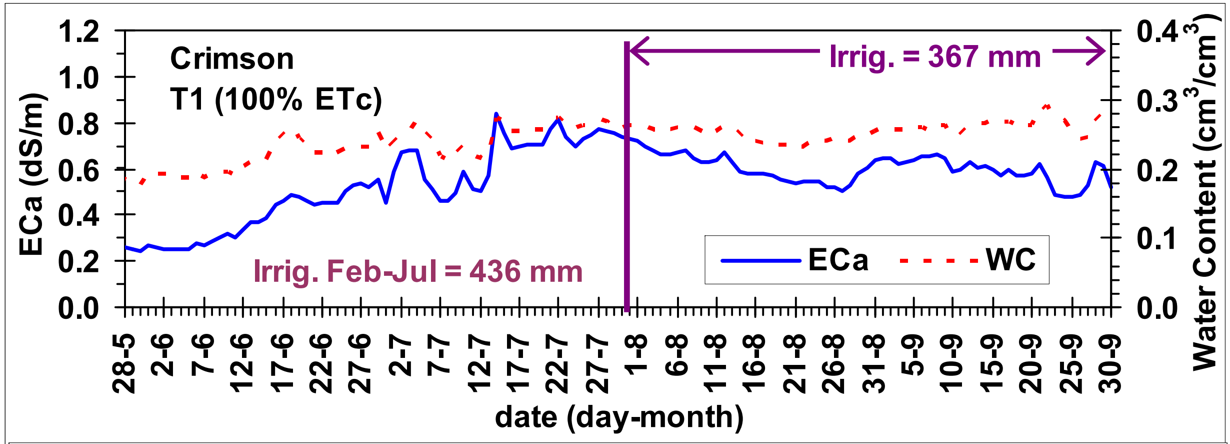


T2	ECa	θ
Mean	0.77	0.31
St. D.	0.20	0.02
CV (%)	26	5
Mean Aug-Se	0.72	0.31

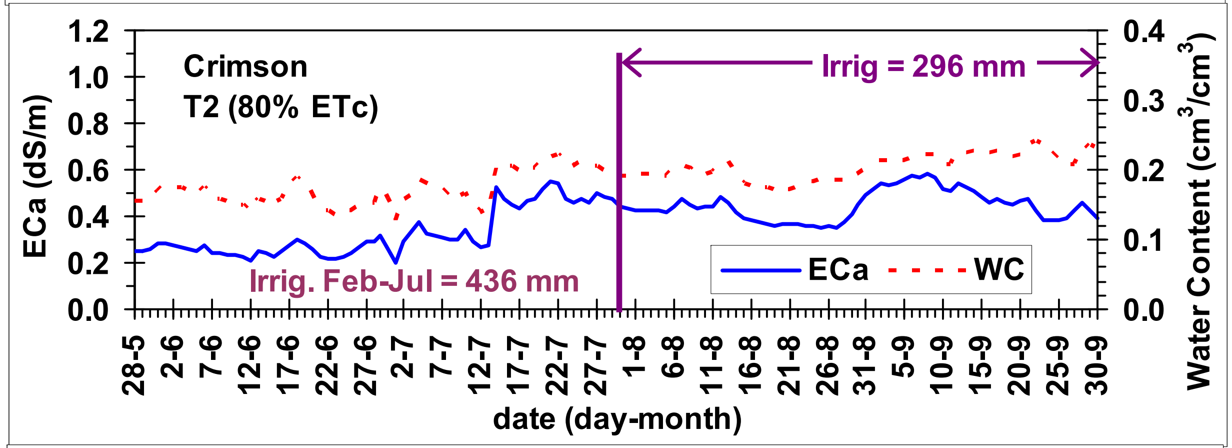


T3	ECa	θ
Mean	0.58	0.27
St. D.	0.18	0.02
CV (%)	30	6
Mean Aug-Se	0.65	0.27

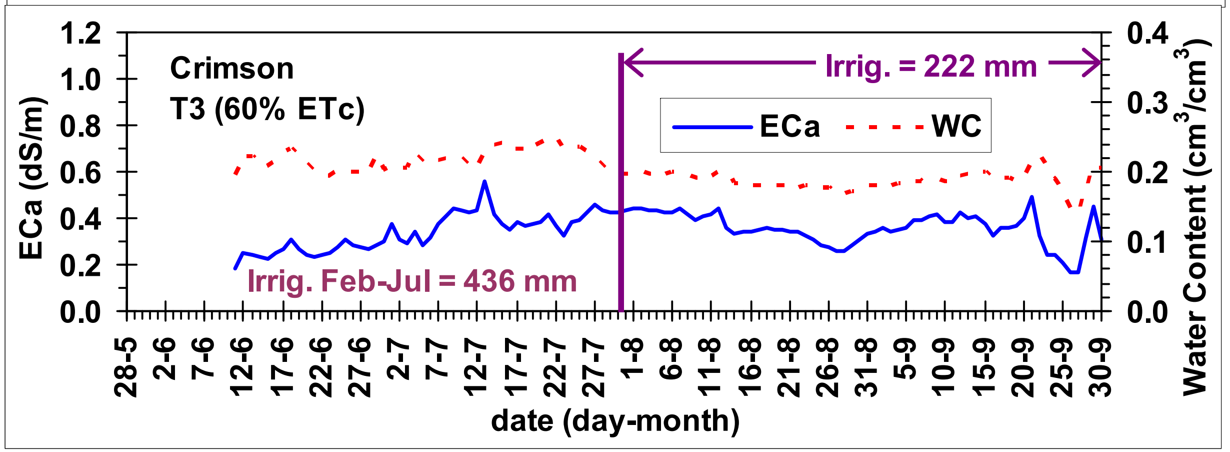
• Hydraprobe II: ECa and θ in Crimson



T1	ECa	θ
Mean	0.38	0.19
St. D.	0.11	0.03
CV (%)	28	15
Mean Aug-Se	0.45	0.20



T2	ECa	θ
Mean	0.35	0.20
St. D.	0.07	0.02
CV (%)	21	10
Mean Aug-Se	0.36	0.19



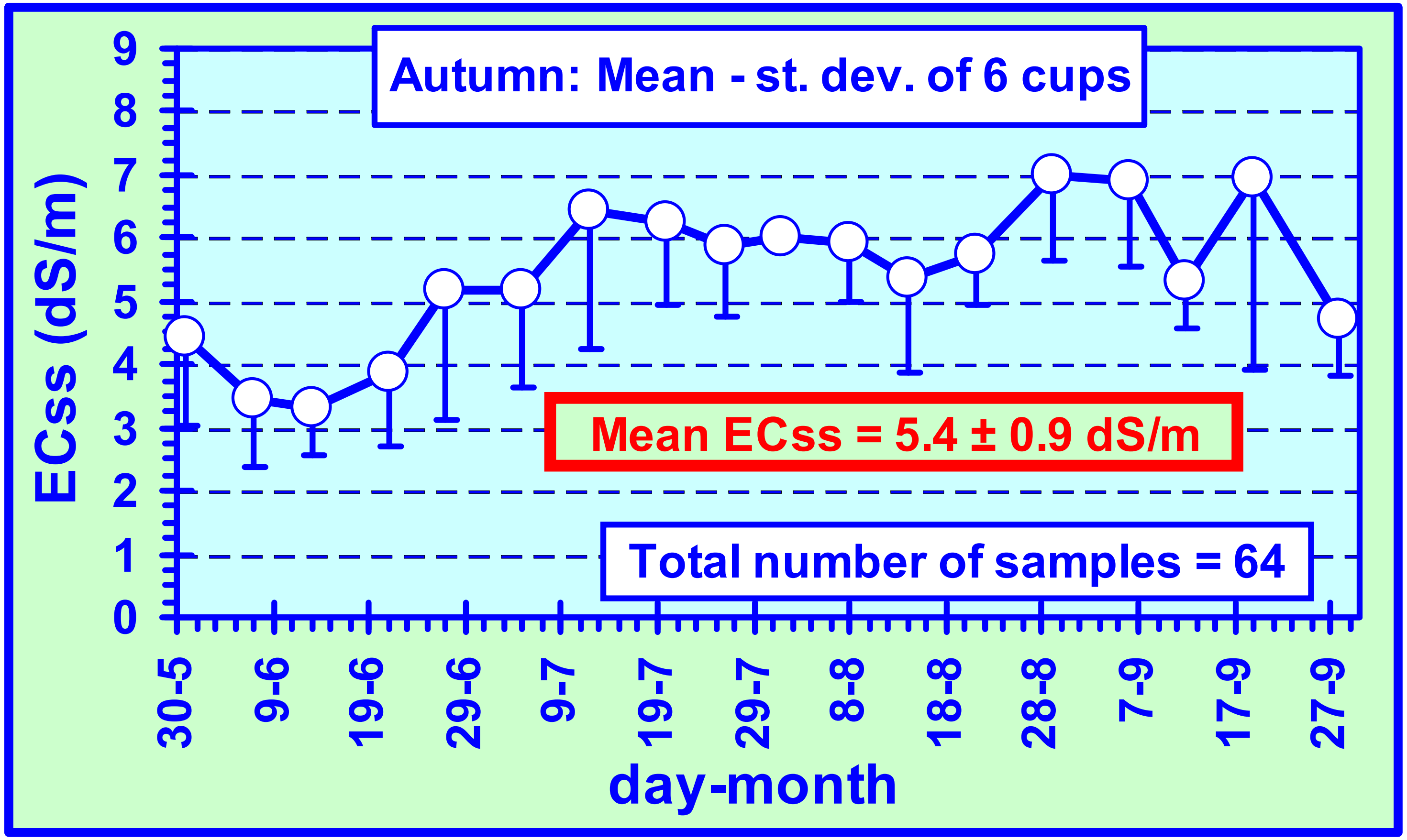
T3	ECa	θ
Mean	0.55	0.24
St. D.	0.15	0.03
CV (%)	27	11
Mean Aug-Se	0.60	0.26

- **Hydraprobe II – tentative conclusions in 2007**

		Autumn			Crimson		
		T1	T2	T3	T1	T2	T3
Jun-Sep	ECa (dS/m)	0.37	0.77	0.58	0.38	0.35	0.55
	θ (cm^3/cm^3	0.22	0.31	0.27	0.19	0.20	0.24
Aug-Sep (CDI)	ECa (dS/m)	0.42	0.72	0.65	0.45	0.36	0.60
	θ (cm^3/cm^3	0.23	0.31	0.27	0.20	0.19	0.26

1. **ECa affected by θ.**
2. **ECa Autumn (mean Jun-Sep = 0.57) > ECa Crimson (mean = 0.43); but θ Autumn (mean = 0.27) > θ Crimson (mean = 0.21).**
3. **T3: θ in Aug-Sept ≥ θ in Jun-Sep. Inconsistent, since θ in T3 should decrease in Aug-Sept because of CDI.**
4. **ECa Aug-Sep > ECa Jun-Sep in T1 and T3 for similar θ values ⇒ ECa increased due to an increase in soil solution salinity? Why not in T2?**

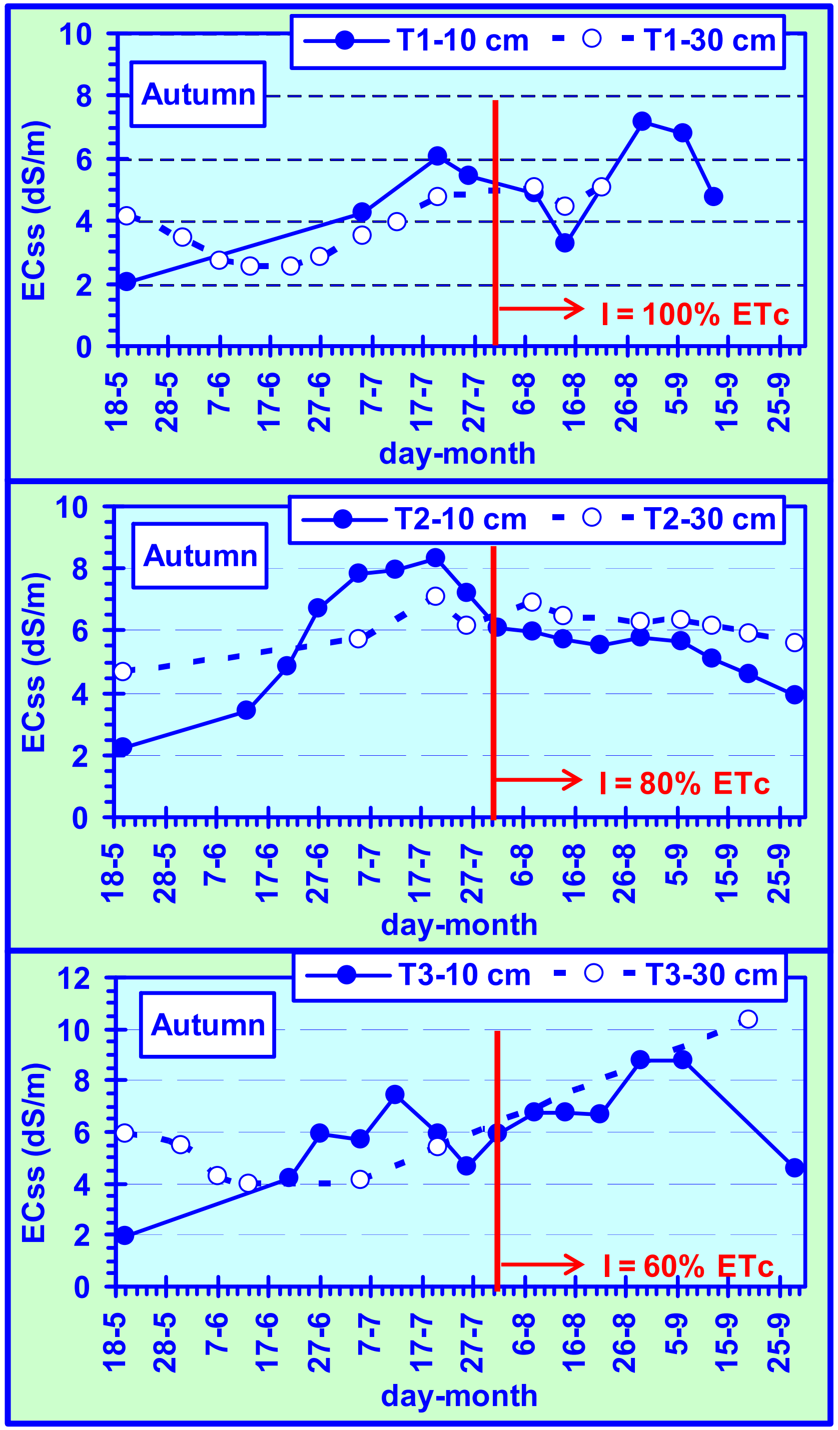
Suction cup - Autumn



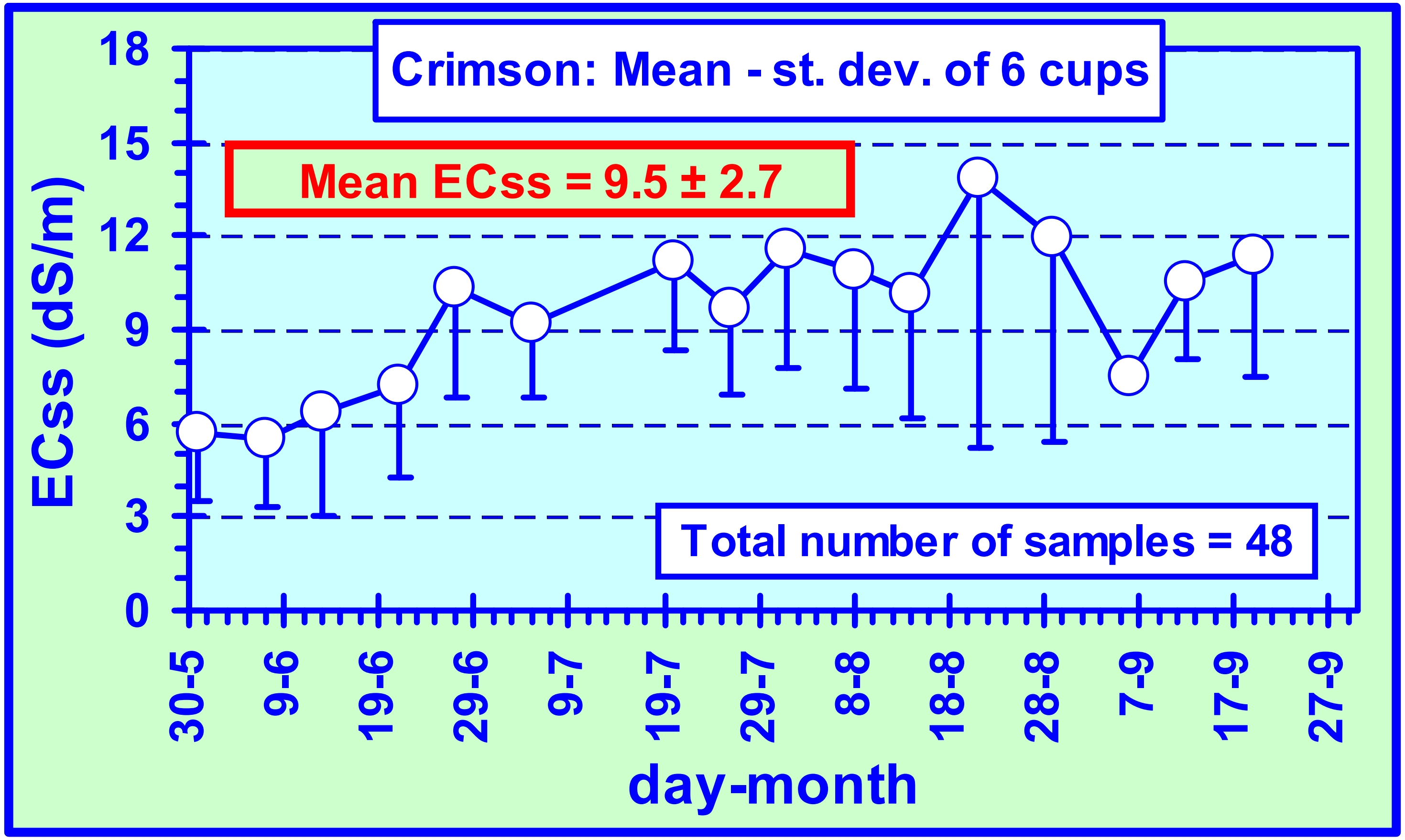
- 64 soil solution samples taken for a total of 120 imposed.
- Increase of ECss until mid September.
- Mean ECss = 5.4 dS/m ≈ 2.6 dS/m ECe.
- ECe 90% grapevine = 2.5 dS/m ⇒ Low or nil yield decrease.

Suction cup - Autumn

- Comparisons for SC at 10 and 30 cm from emitter difficult because of lack of extraction in T1 and T3 for SC at 30 cm.
- ECss decreases in T2 after CDI (I = 80% ETc) is imposed. Inconsistent.
- ECss increases in T3 after CDI (I = 60% ETc) is imposed. Consistent.



Suction cup - Crimson

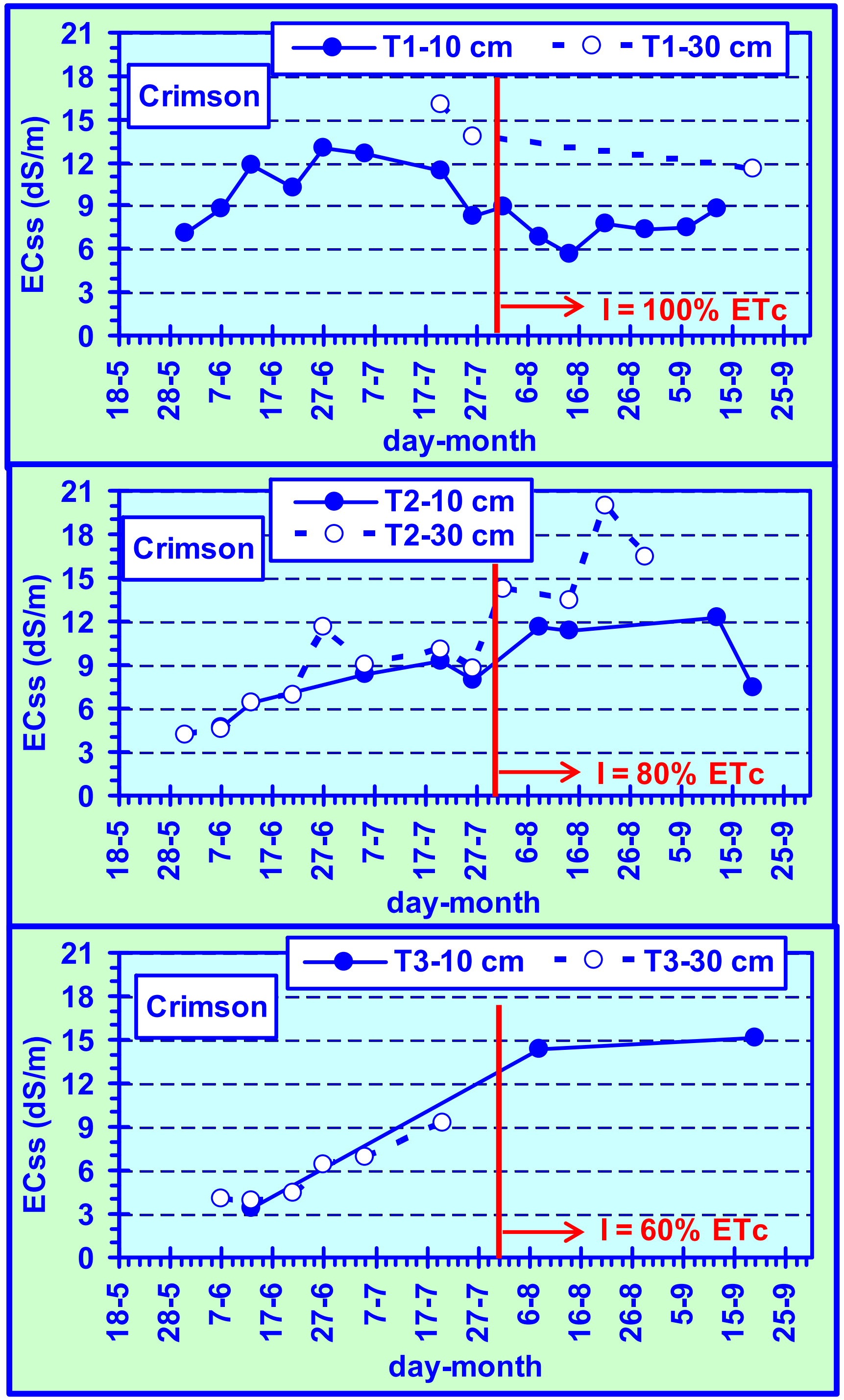


- 48 soil solution samples taken for a total of 96 imposed.
- Increase of ECss until mid September.
- Mean ECss = 9.5 dS/m ≈ 4.8 dS/m ECe.
- ECe 90% grapevine = 2.5 dS/m ⇒ 30% yield decline.

Suction cup - Crimson

- Comparisons for SC at 10 and 30 cm from emitter difficult. In general, ECss 30 cm > ECss 10 cm.

- ECss increases in T2 and T3 after CDI is imposed. But number of samples extracted is low to make consistent conclusions.



Suction cup: comparisons of ECss at 10 and 30 cm from emitter (only for samples extracted in the same date)

ECss (dS/m)	AUTUMN				CRIMSON			
	Treatment				Treatment			
	T1	T2	T3	All	T1	T2	T3	All
ECss- 10 cm	4.1	5.7	4.5	4.8	9.9	7.3	3.4	6.9
ECss- 30 cm	4.4	6.1	5.1	5.2	14.9	7.7	4.0	8.9
Nº samples	5	11	3	19	2	2	1	5

- **Although the number of soil solution samples is insufficient to obtain solid conclusions, ECss at 30 cm from emitter is always higher than ECss at 10 cm from emitter.**
- **Consistent with hypothesis in that ECss increases with distance from emitter.**

Suction cup: increases in salinity among treatments (only for ECss at 10 cm, where maximum number of samples were extracted)

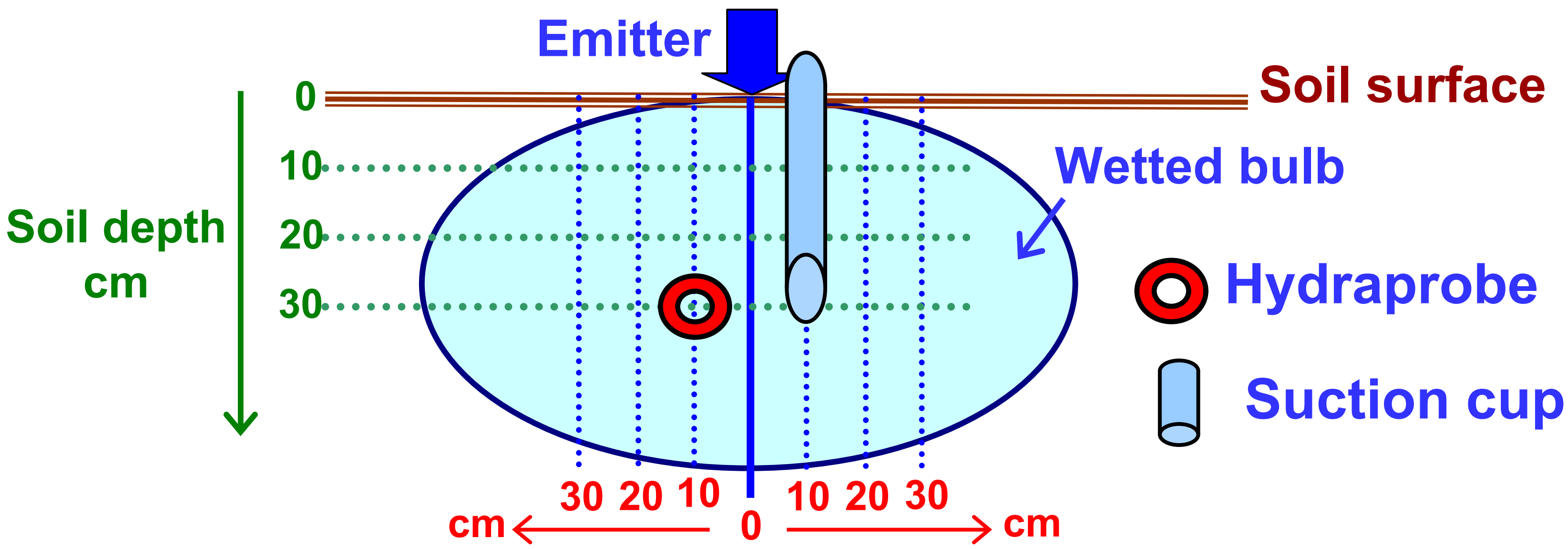
Average ECss for SC at 10 cm from emitter	AUTUMN				CRIMSON			
	Treatment				Treatment			
	T1	T2	T3	All	T1	T2	T3	All
ECss (dS/m)	5.0	5.7	6.0	5.6	9.1	8.8	11.0	9.5
% variation from T1	0	14	20	8	0	- 3	21	4

- **In relation to T1 (100% ETc treatment), soil solution salinity in the higher water-stress treatment (T3, 60% ETc) increased by 20% in both varieties.**
- **Consistent with hypothesis that the higher the water stress, the higher the soil salinization.**

Suction cup: tentative conclusions in 2007

1. Only 50% success in extraction of soil solution.
2. ECss doubles along the studied period (June to September), from around 3.5 to 7 dS/m in Autumn, and from 6 to 12 dS/m in Crimson.
3. ECss at 30 cm from emitter > ECss at 10 cm from emitter.
4. In relation to non-stressed T1 treatment, ECss of the highest-stressed treatment (T3) increases by 20% in both varieties.
5. Treatment's average: ECss Crimson (9.5 dS/m) = 1.8 · ECss Autumn (5.4 dS/m).
6. Assuming ECe = 0.5 · ECss and a threshold ECe-90% for grapevine = 2.5, Autumn has not yield decline, whereas Crimson will have a 30% yield decline.

Hydraprobe (ECa, θ) – Suction cup (CEss) relationships



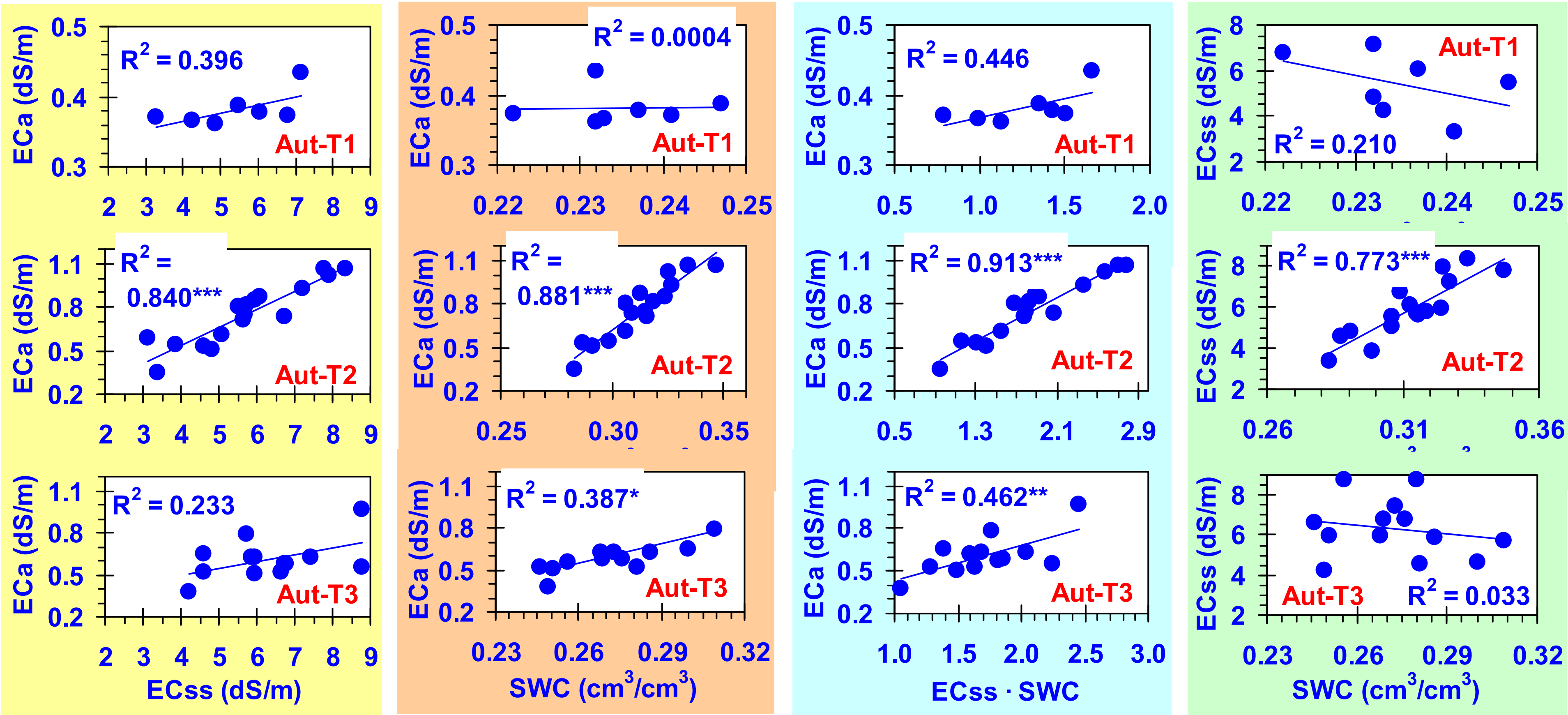
- Comparisons for instruments installed at 10 cm from emitter (total: 2 varieties x (T1, T2, T3) = 6 observations).
- Comparisons performed between mean ECa of 10 min readings taken along 24 h after vacuum application to suction cups, and ECss extracted 24 h after vacuum application.
- Caution: ECa- θ data taken in the same point; but ECa-ECss data taken in two different points.

Mean θ (cm^3/cm^3), ECa (dS/m) and ECss (dS/m) for T1, T2 and T3 treatments

	AUTUMN				CRIMSON			
	T1	T2	T3	All	T1	T2	T3	All
θ	0.22	0.31	0.27	0.27	0.19	0.20	0.24	0.21
ECa	0.37	0.77	0.58	0.57	0.38	0.35	0.55	0.43
ECss	5.0	5.7	6.0	5.6	9.1	8.8	11.0	9.5

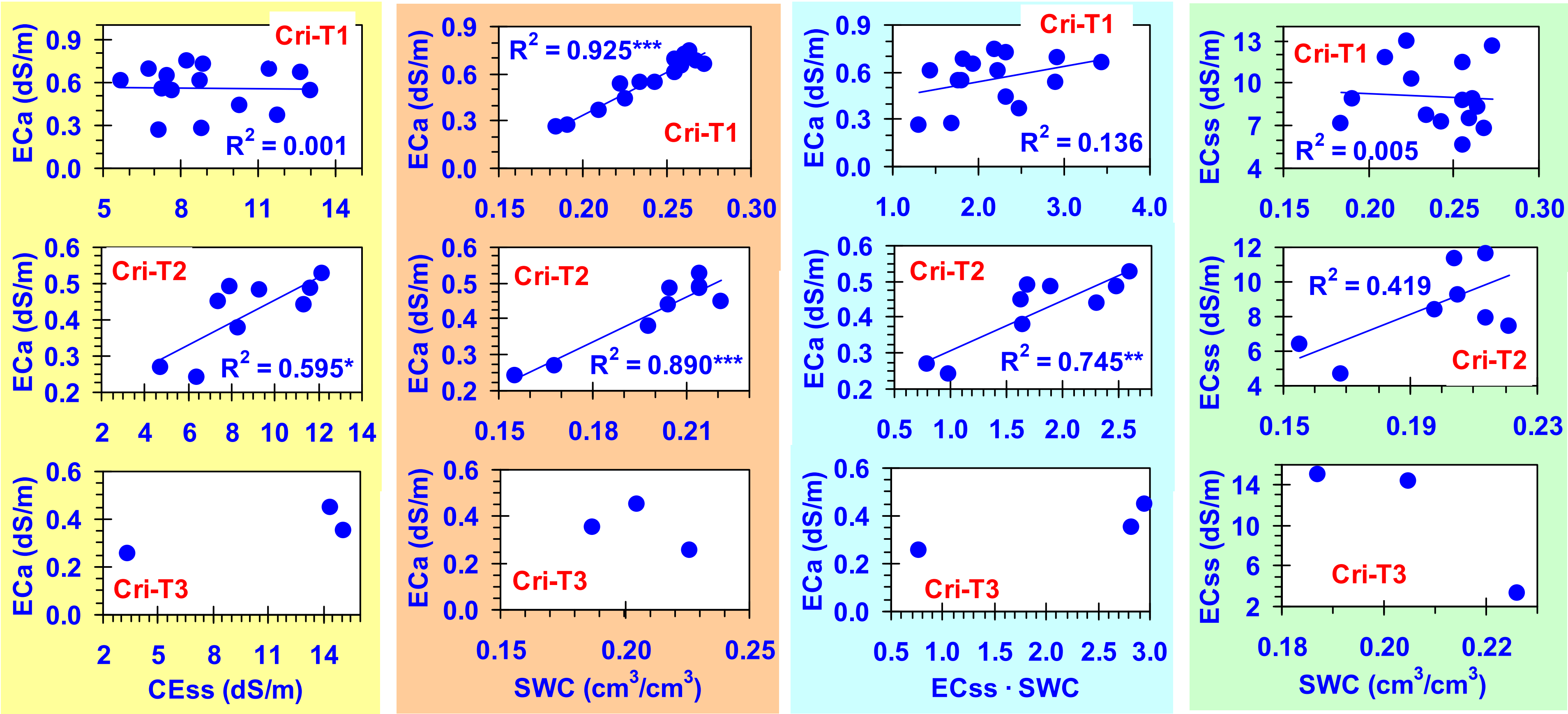
- ECss Autumn << ECss Crimson.
- ECa Autumn ≥ ECa Crimson.
- Inconsistent ECa results.
- Could be due to the effect of soil water content on ECa? (i.e., θ Autumn > θ Crimson)
- ECa-ECss- θ regression analysis

Autumn: ECa-ECss- θ regression analysis



- Only one ECa-ECss significant regression (P < 0.001)
- ECa better correlated with θ (SWC) than with ECss
- ECa better correlated with ECss · θ (as in EM measurements)
- ECss positively correlated with SWC in T2. Inconsistent?

Crimson: ECa-ECss- θ regression analysis



- Only one ECa-ECss significant regression ($P < 0.05$)
- ECa better correlated with θ (SWC) than with ECss
- ECa is not better correlated with ECss · θ than with θ
- Only three observations in T3: LRA not performed.

Autumn & Crimson
ECa-ECss- θ regression analysis

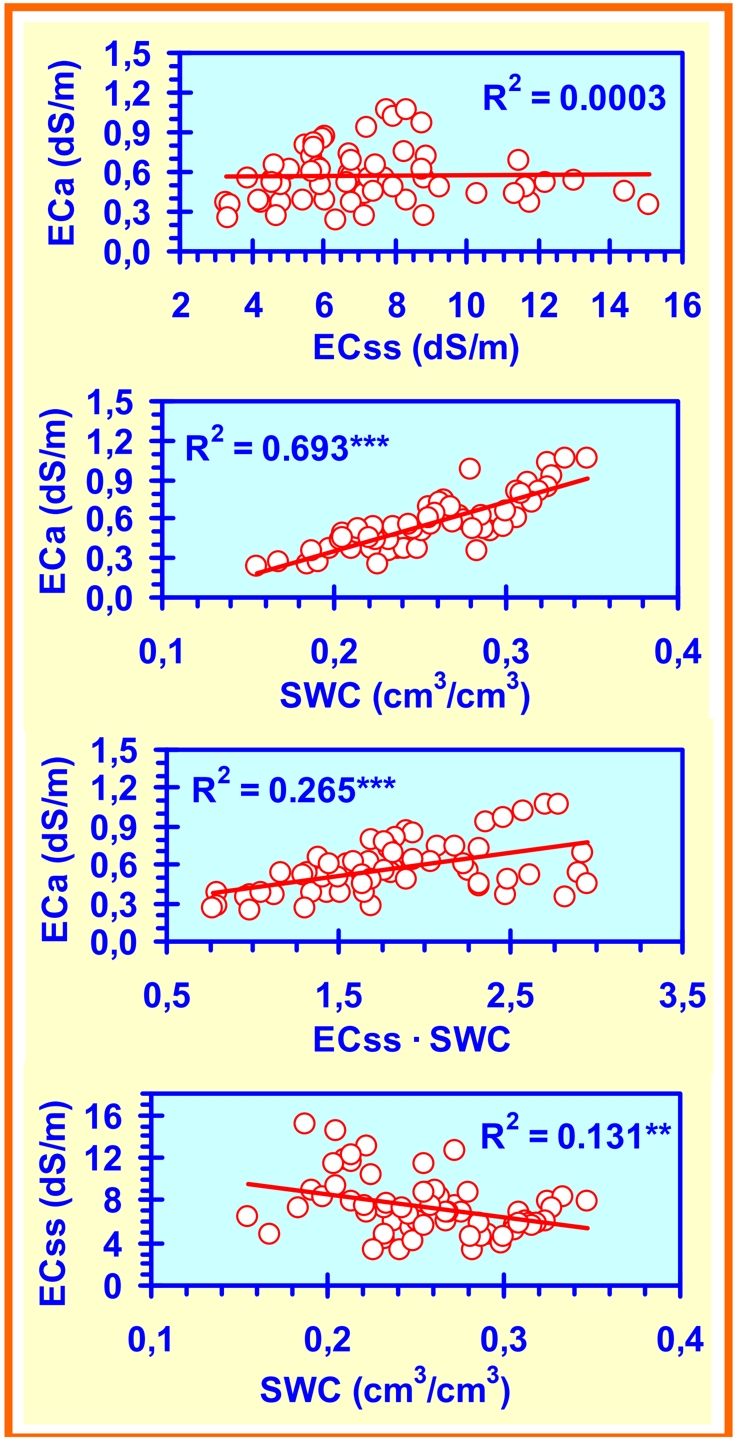
GENERAL CONCLUSIONS

1- ECa and ECss not correlated.

2- ECa and soil water content (SWC) significantly correlated ($P < 0.001$).

3- ECa and ECss · SWC significantly correlated ($P < 0.001$).

4- ECss and SWC negatively correlated ($P < 0.01$).



Why soil salinity in Crimson almost doubles soil salinity in Autumn if same soil, same topographic position, same irrigation water EC, same irrigation management...?

- ET Crimson > ET Autumn?

  - Earlier sprouting (16 days) and flowering (8 days) in Crimson than in Autumn ⇒ higher ET in Crimson.

	Sprouting	Blooming	Veraison	Harvesting
Autumn	29/03/07	31/05/07	07/08/07	02/10/07
Crimson	13/03/07	23/05/07	30/07/07	01/10/07

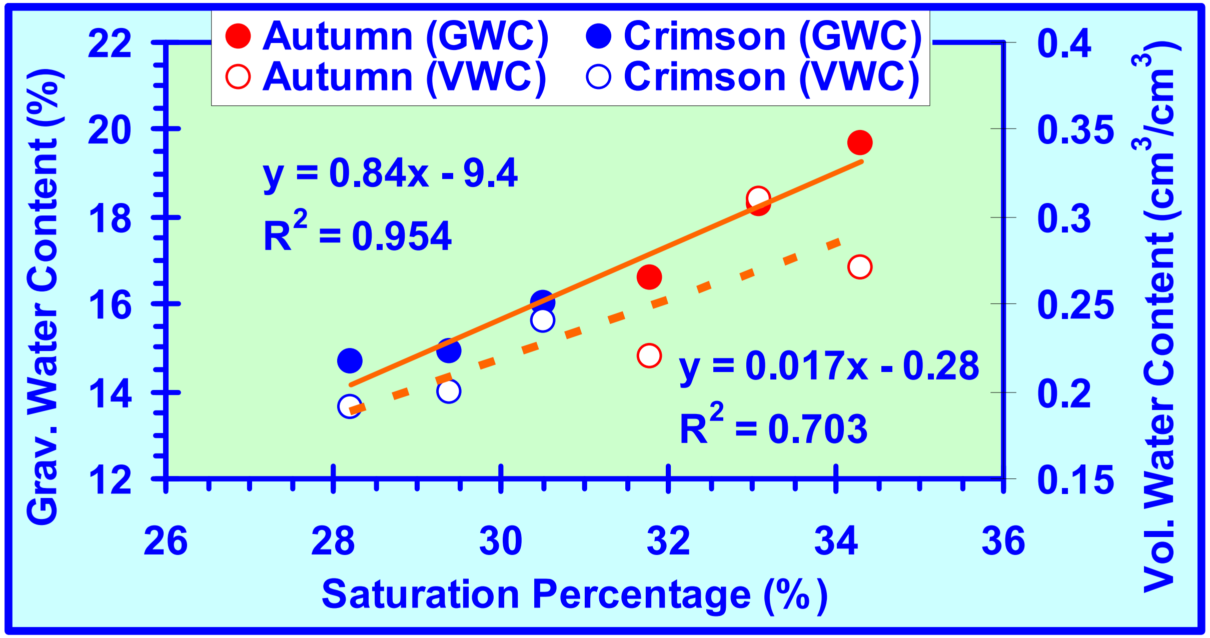
  - Higher ET will imply higher evapo-concentration and higher soil salinity in Crimson.

  - ET will be measured in 2008 with sap-flow instruments.

- **Saturation percentage (SP) in Autumn (33.1%) is 13% higher than in Crimson (29.4%)**

⇒ Higher soil water content in Autumn than in Crimson

Soil water content	Autumn	Crimson	% diff.
Gravimetric (soil sampling)	18.2 g/100g	15.2 g/100 g	20%
Volumetric (Hydraprobe)	0.27 cm^3/cm^3	0.21 cm^3/cm^3	29%



⇒ For a given ET, the lower the SP, the lower the residual soil water content, the higher the ET-concentration factor, and the higher the soil salinity.

Final remarks...

- Soil salinity is a relevant problem and may be an increasing problem in the study site.
- However, yields are very high (around 45 t/ha), except in Crimson T3, where yield declines by 35%.
- Critical question: how and where grapevines extract the soil solution to satisfy ETc?
- How to properly monitor the salinity of the solution actually being extracted from the soil by grapevines?
- More work in the coming years...

See you in Spain?