A wide-angle photograph of a vast field of red poppies in full bloom. The flowers are densely packed and stretch across the entire foreground and middle ground. The sky is a clear, pale blue, and the horizon is visible in the distance with some faint structures and trees. The overall scene is bright and vibrant.

Optimizing water productivity in food production

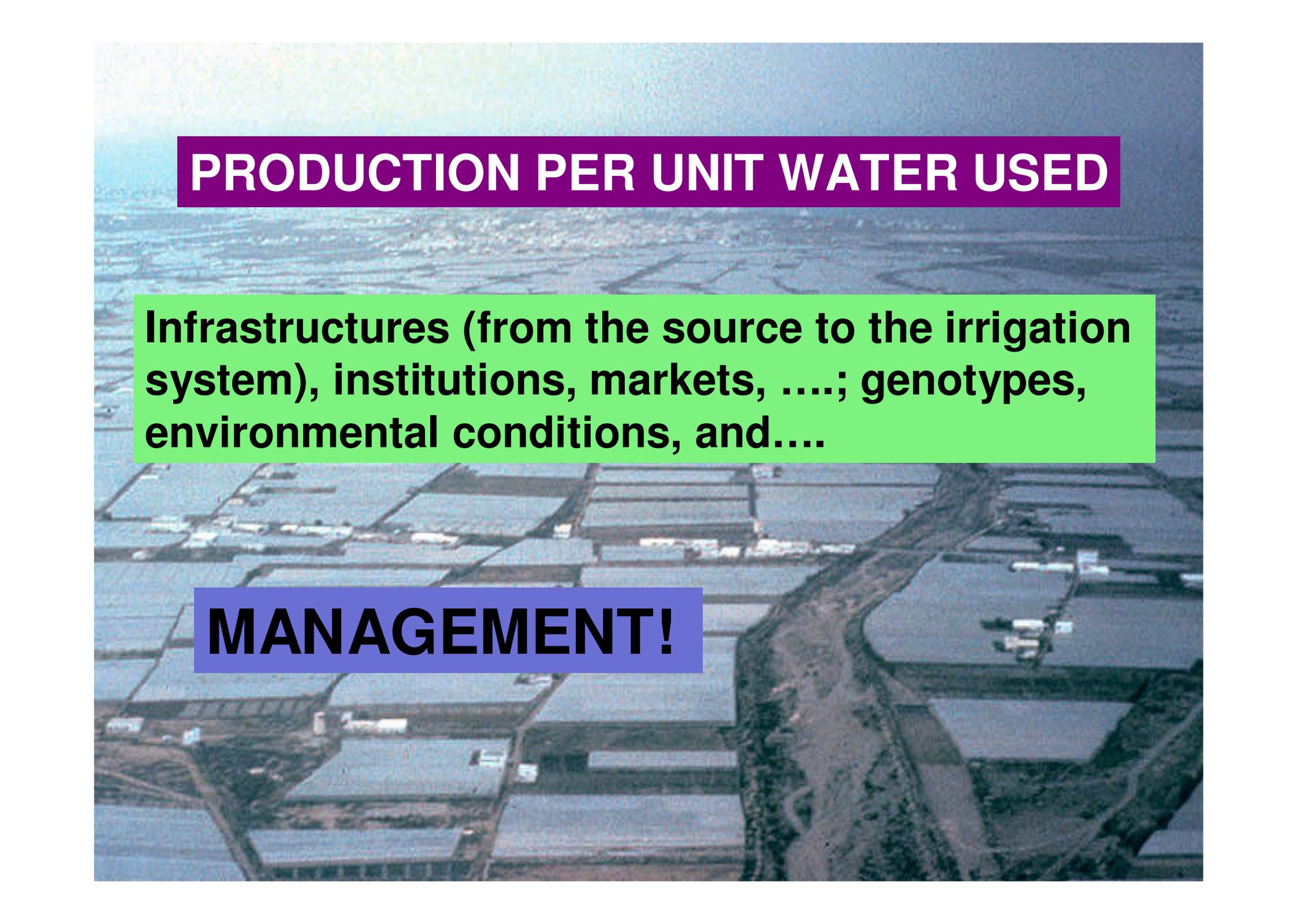
THE ROSENBERG FORUM, ZARAGOZA, 2008

ELIAS FERERES

**INSTITUTE FOR SUSTAINABLE AGRICULTURE-CSIC &
UNIVERSITY OF CORDOBA, SPAIN**

$$E_P = \frac{W_{tr}}{W_{re}} = \frac{W_{fg}}{W_{re}} \times \frac{W_{fe}}{W_{fg}} \times \frac{W_{rz}}{W_{fe}} \times \frac{W_{et}}{W_{rz}} \times \frac{W_{tr}}{W_{et}}$$

**IMPROVING THE EFFICIENCY OF WATER
USE REQUIRES A MULTIDISCIPLINARY
APPROACH, COMBINING (Bio-physical
and social) SCIENCES AND
ENGINEERING APPLICATIONS**



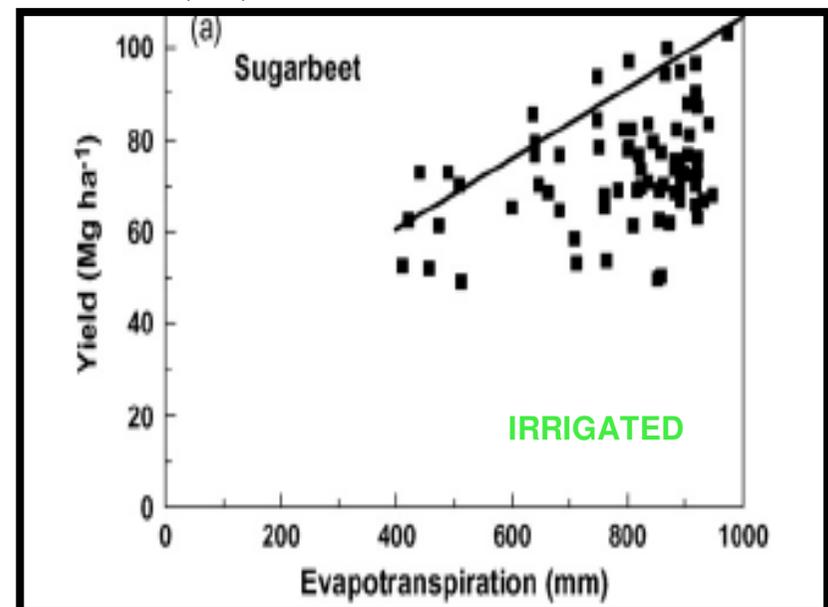
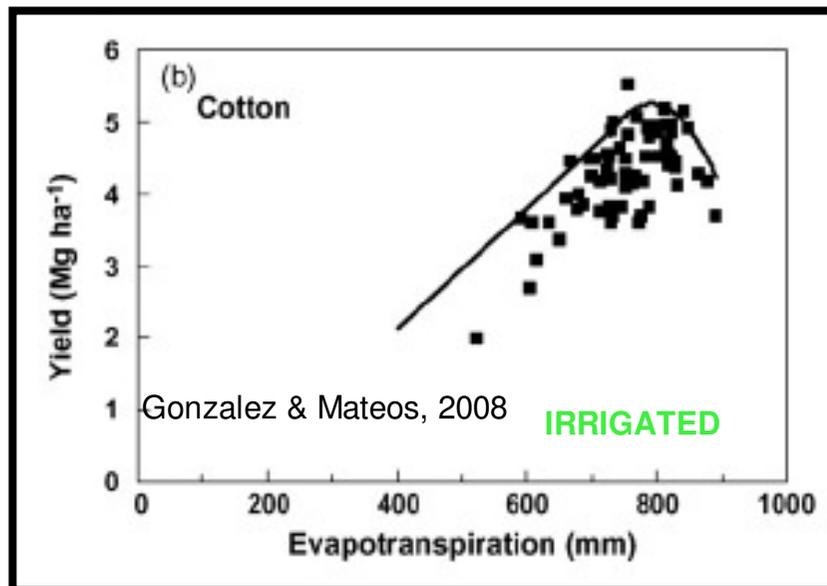
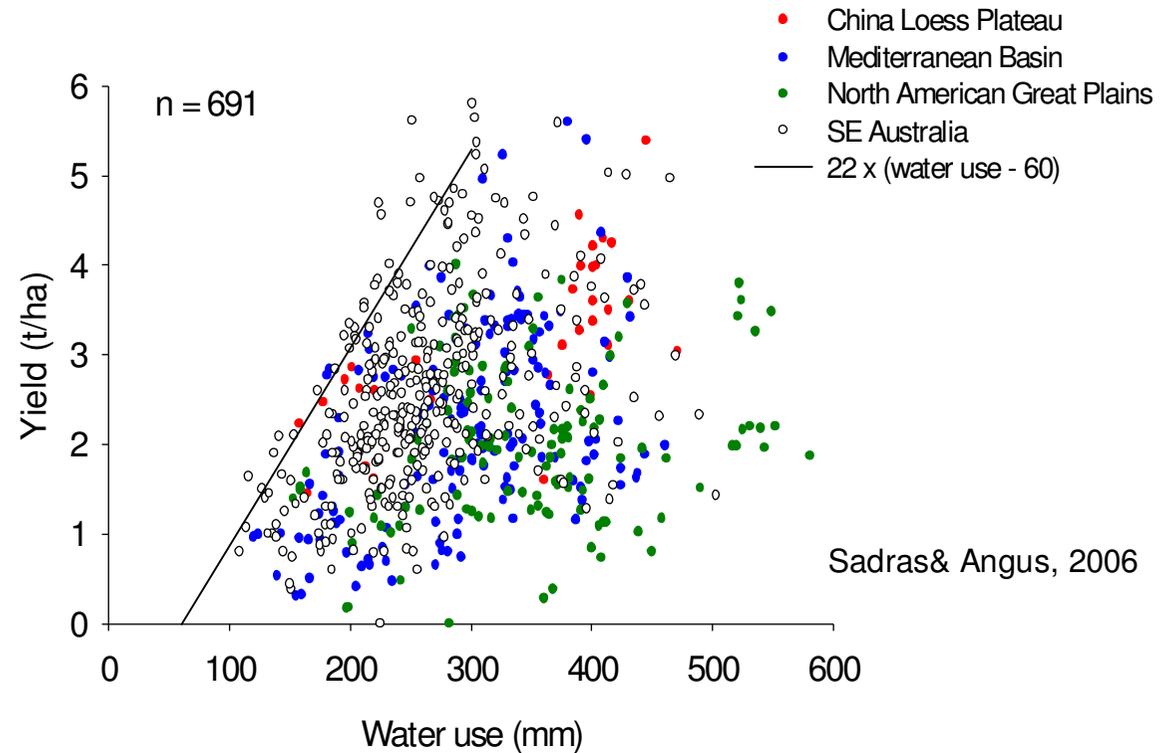
PRODUCTION PER UNIT WATER USED

Infrastructures (from the source to the irrigation system), institutions, markets,; genotypes, environmental conditions, and....

MANAGEMENT!

**EFFICIENCY OF
WATER USE IS
OFTEN LIMITED BY
FACTORS OTHER
THAN WATER,**

**IMPROVING
MANAGEMENT AT
ALL LEVELS IS
MOST CRITICAL**



Improving WP in rainfed systems:

$$WP = Y/ET$$

Options: increase Y or decrease ET

$$\text{Yield} = \text{Transpiration} \times \text{Transp. Eff. (WPb)} \times \text{Harvest Index}$$

$$Y \text{ (kg/ha)} = T \text{ (mm)} \times TE \text{ (kg/ha/mm)} \times HI \text{ (kg/kg)}$$

Options: Biological, Environmental and Management

What can we expect from GM crops?

Can we predict/change the environment?

How to best manage rainfed systems?

Objectives: maximize the fraction of rainfall into T and maintain HI

New Indian Bed Planter Planting Cotton on Permanent Beds in Uzbekistan



Improving WP in Irrigated Agriculture

What has been happening?

1. Changes in irrigation systems.
2. Improved ET estimates and scheduling
3. Shift from low value to high value crops.



(Water saved has been used to expand irrigated areas)

The challenges to further increase W_p in irrigated agriculture

- How much water would be available this season?
- How should I distribute it among crops?
- Optimizing scheduling under Deficit Irrigation
- Applying the water as uniform as possible
- Monitoring, evaluation, and real-time feedbacks to improve performance

Uniformity of water application

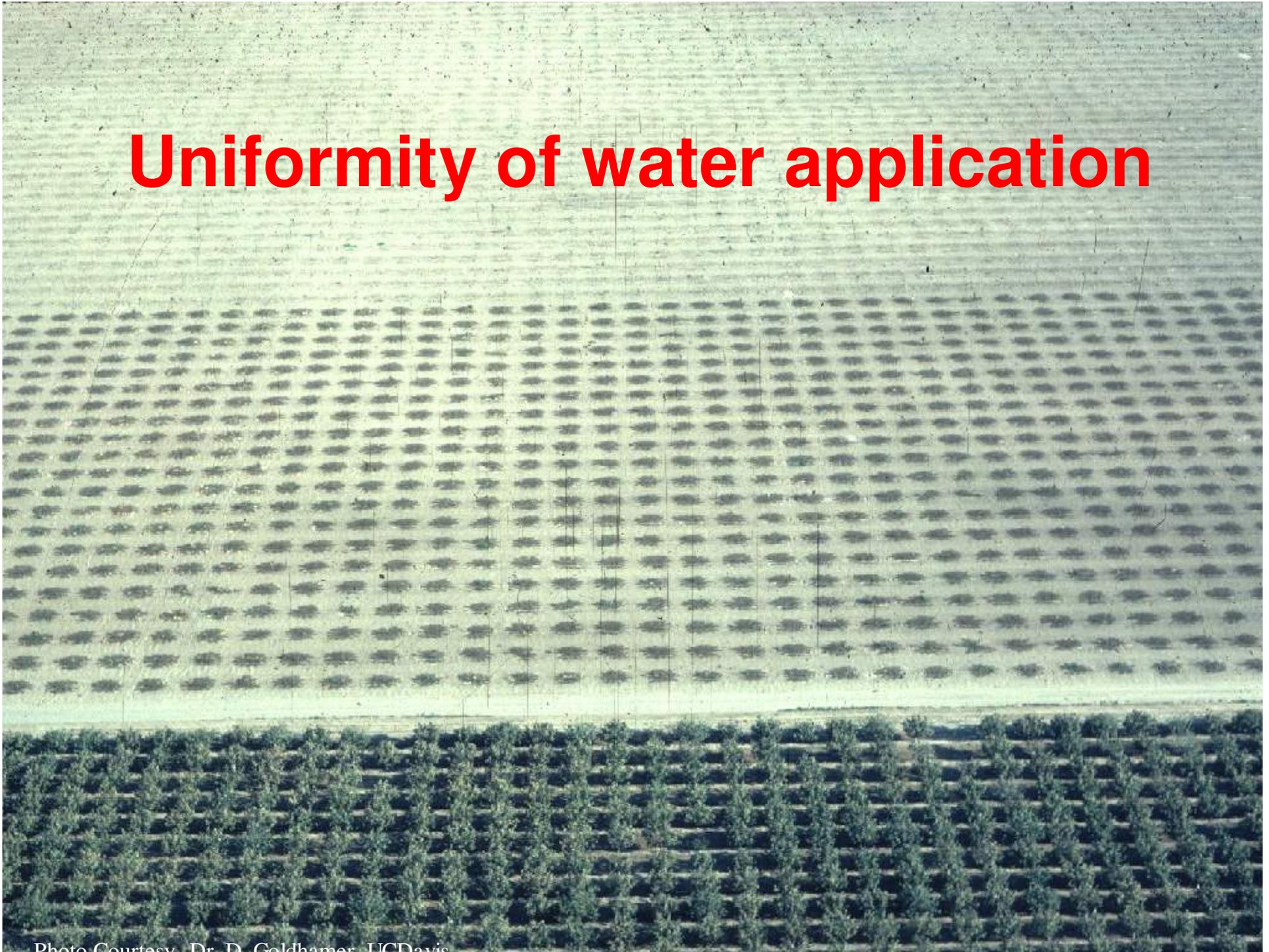
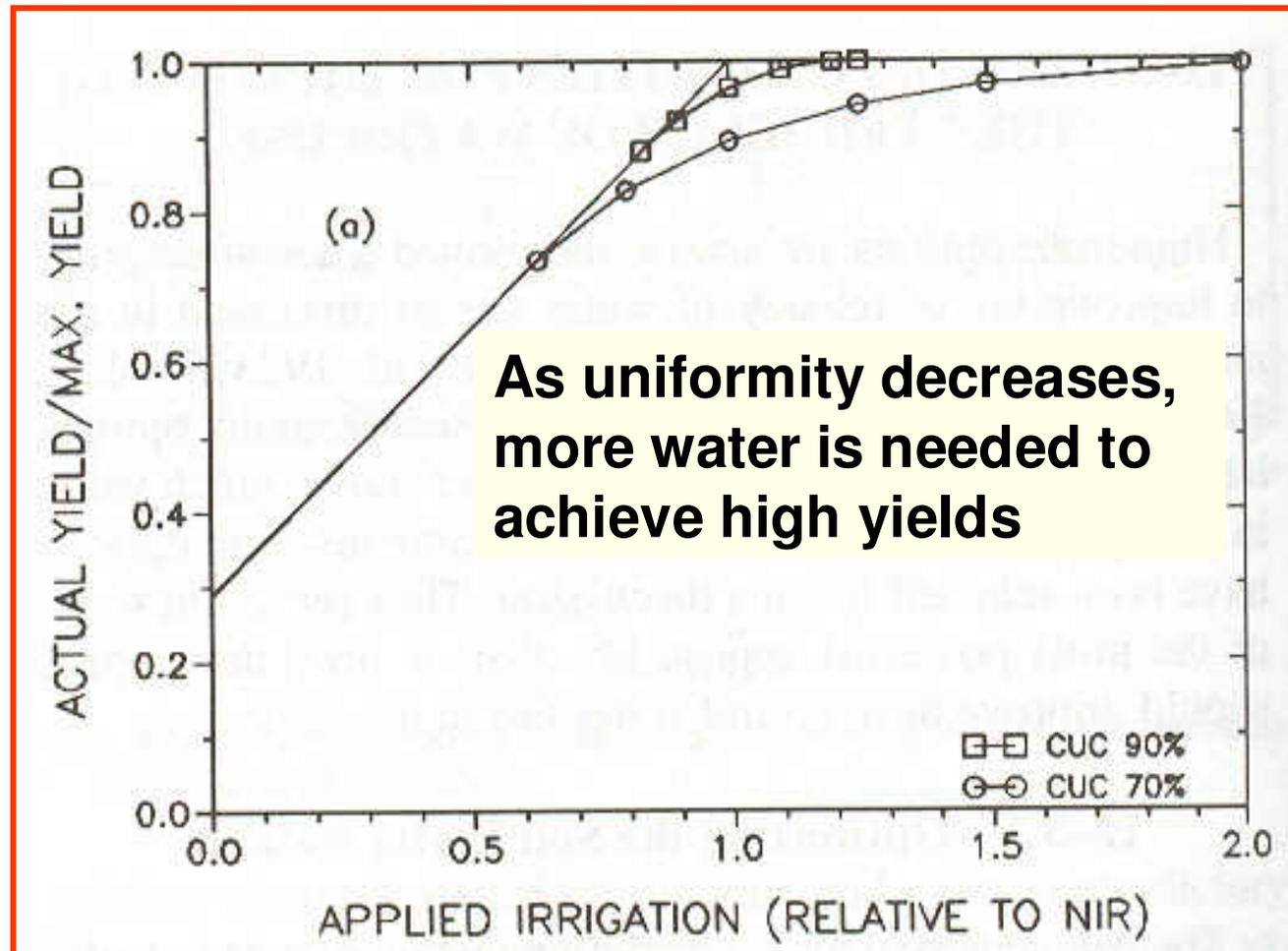


Photo Courtesy: Dr. D. Goldhamer, UC Davis

EFFECTS OF IRRIGATION UNIFORMITY ON THE RELATION BETWEEN YIELD AND IRRIGATION WATER



Fereres et al., 1993, ICSC, Ames, Iowa.

Under Water scarcity,
Reduce Water
Consumption (ET)

Therefore
decrease

E and/or T

**DEFICIT IRRIGATION = APPLICATIONS
BELOW CROP WATER REQUIREMENTS (ET)**

**(Soil water deficits may or may not cause crop water
deficits and reduction in ET)**

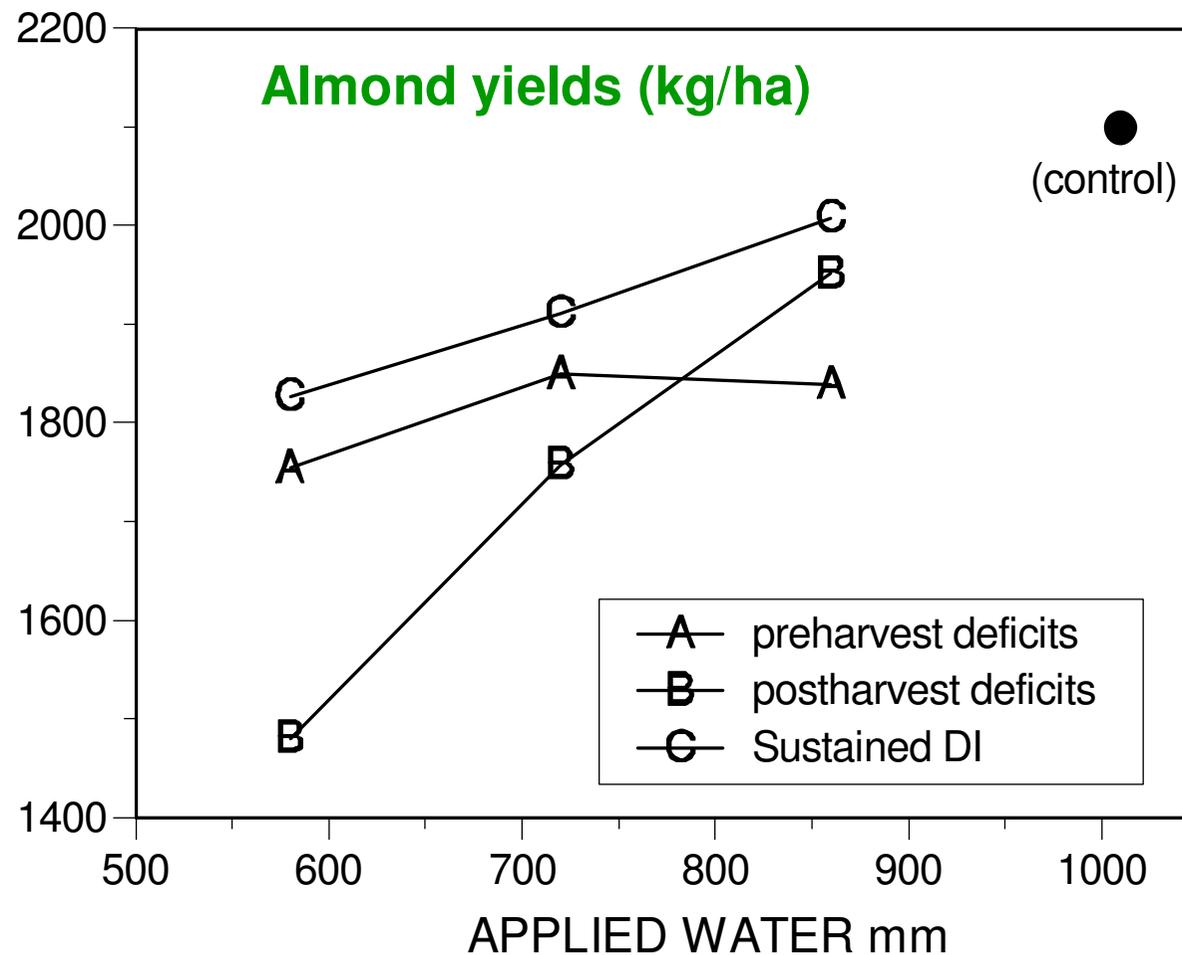
**REGULATED DEFICIT IRRIGATION (RDI) =
PLANNED CROP WATER
DEFICITS AT SPECIFIC DEVELOPMENTAL STAGES.**

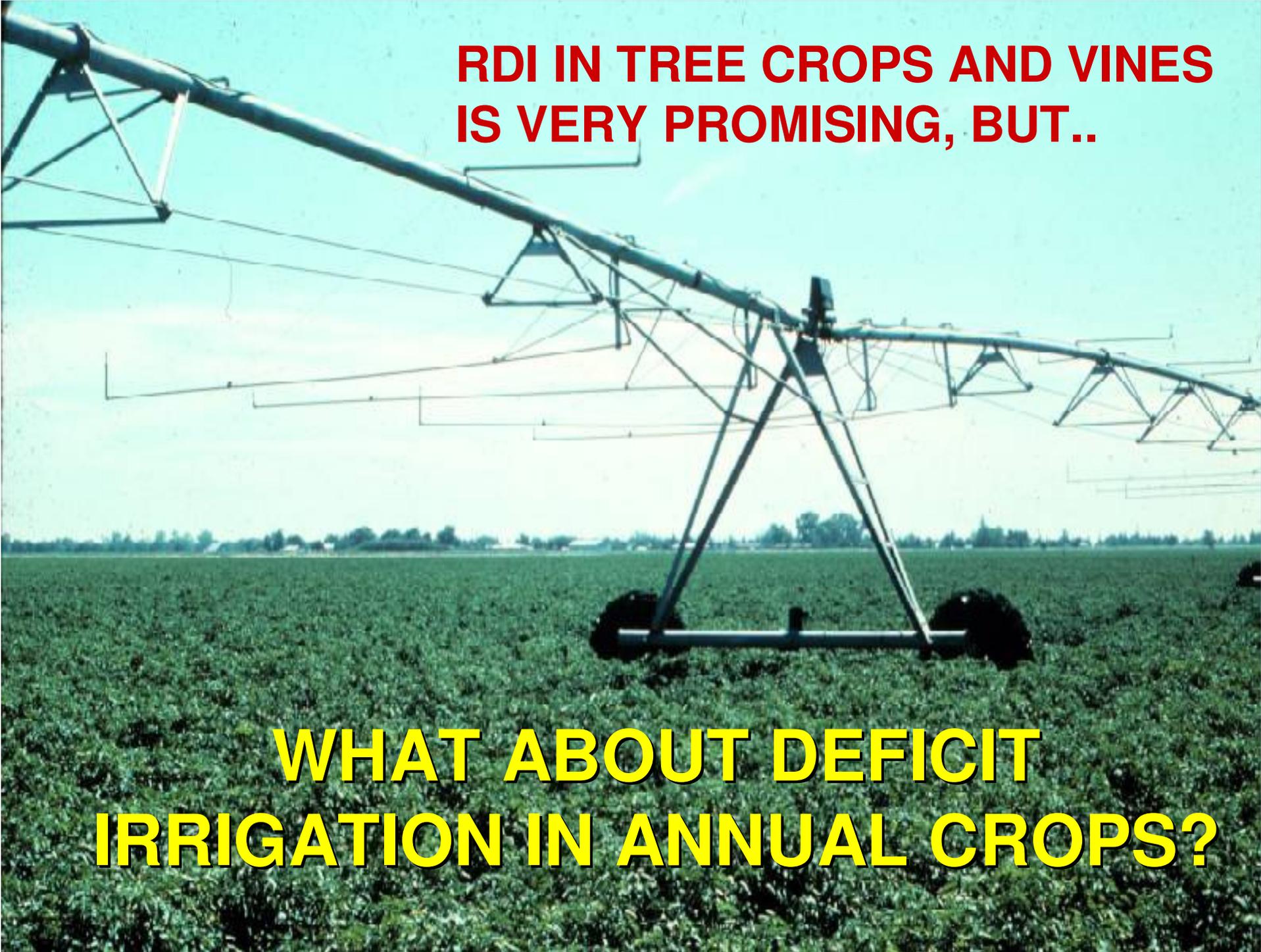
**(Crop water stress occurs at certain stages; ET may or
may not be reduced significantly; RISKS increased)**

Five-year peach experiment in Cordoba, where RDI and SDI were compared to full irrigation; in both DI treatments, 66% of the full requirements was applied

Treatment	Yield (t ha ⁻¹)	Fruit volume (FV cm ³)	Relative FV
Full	42.2 a	213 a	100
SDI	38.6 b	198 b	92.9
RDI	41.2 a	213 a	100

There is always an optimal Deficit Irrigation strategy that must be determined through long-term research!



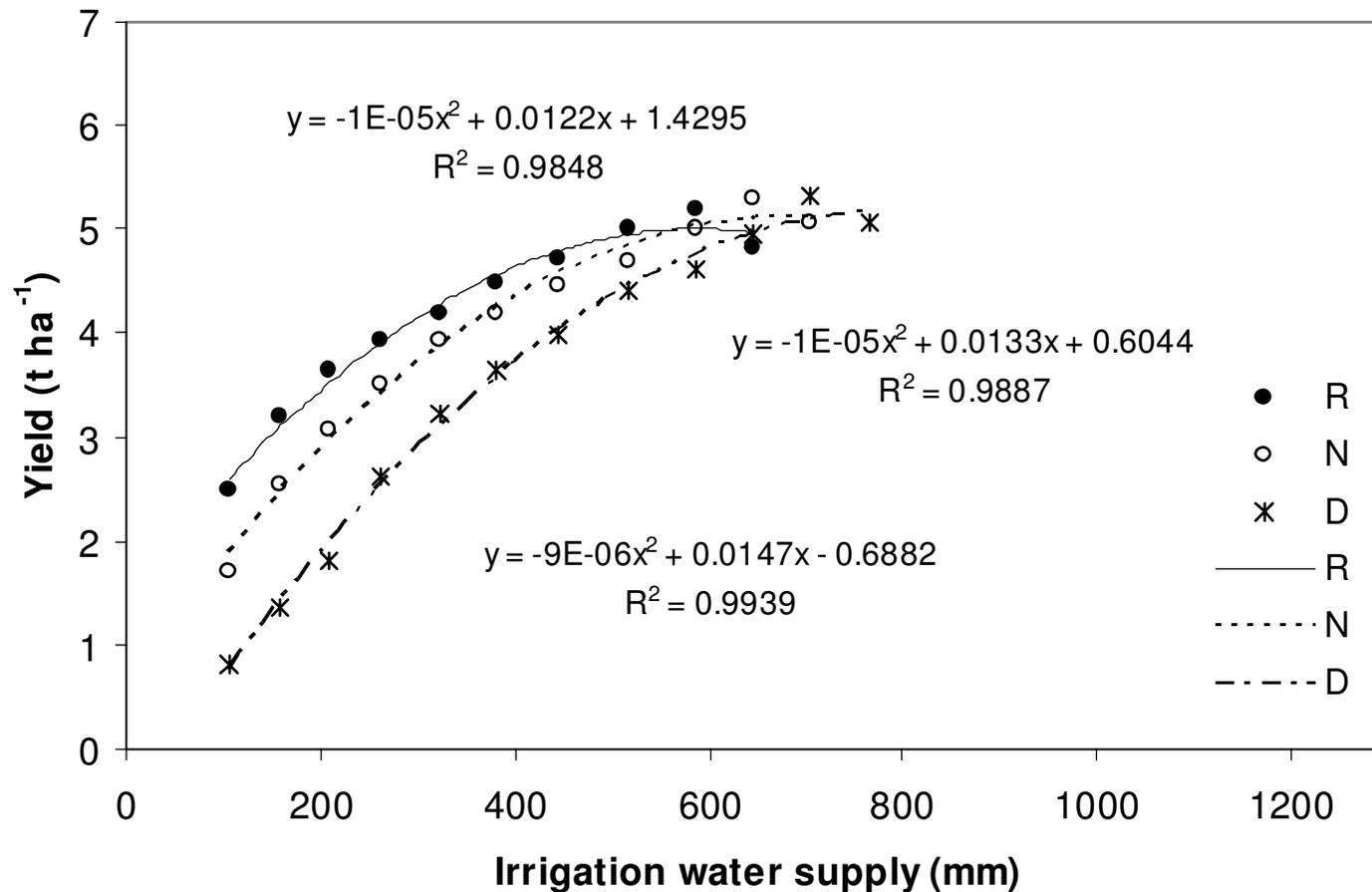
A large center pivot irrigation system is shown over a vast green field. The system consists of a long metal wheel line supported by multiple truss-like structures, with numerous smaller lateral lines extending from it. The field below is densely packed with green crops. The sky is clear and blue.

**RDI IN TREE CROPS AND VINES
IS VERY PROMISING, BUT..**

**WHAT ABOUT DEFICIT
IRRIGATION IN ANNUAL CROPS?**

COTTON YIELD RESPONSE TO WATER IN SOUTHERN SPAIN

The yield-response function was generated for wet (R), normal (N), and dry (D) years, **using a computer simulation model.**



COMPUTER MODELS FOR PLANNING AND MANAGEMENT

AquaCrop: a simulation model of water-limited crop production, currently being developed in FAO by P. Steduto, T. Hsiao, D. Raes, and E. Fereres.



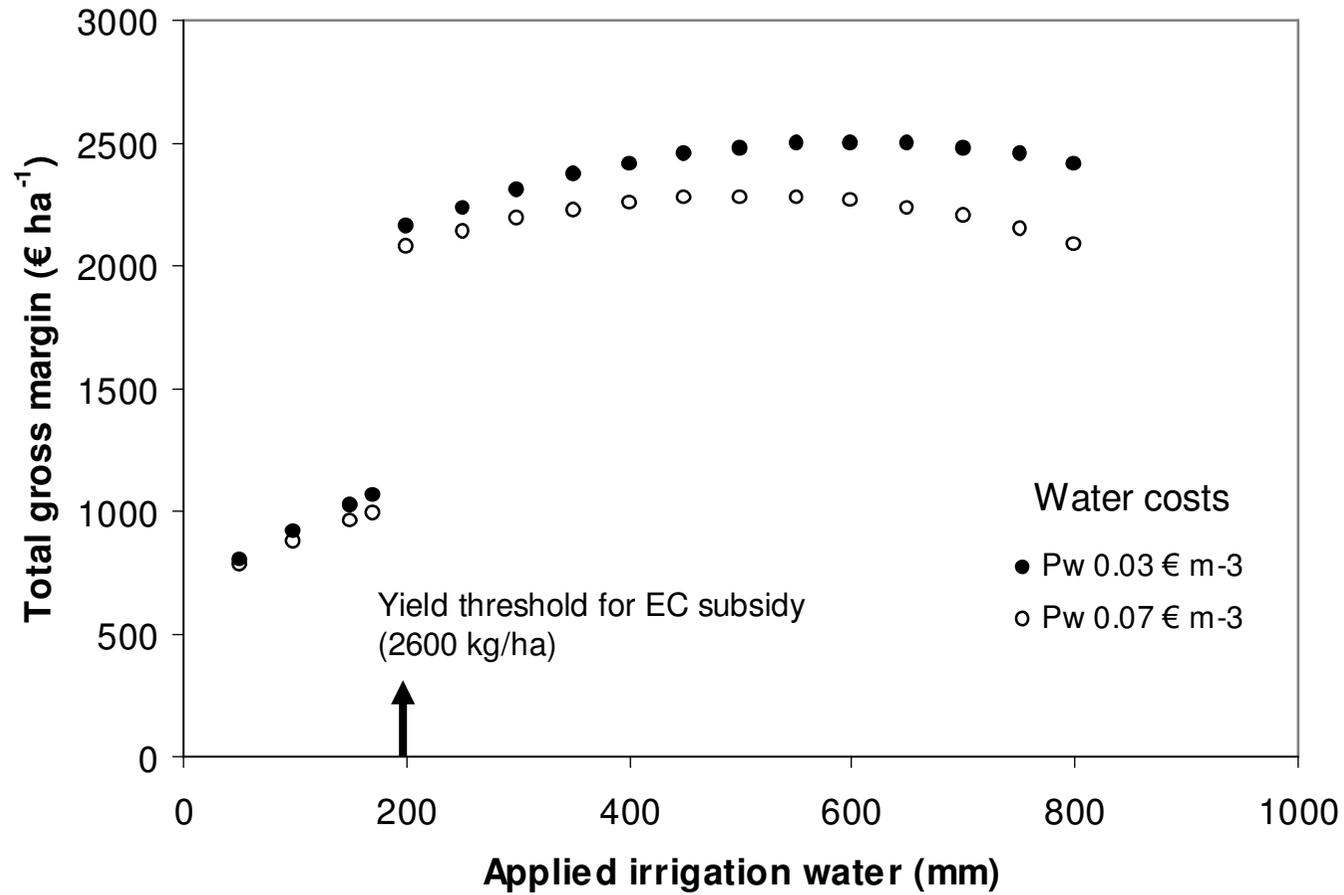
The screenshot displays the 'Main menu' window of the AquaCrop simulation software. The interface is organized into several sections:

- Data Base:** A table with columns for 'File Name' and 'Description'. It lists four categories: Climate (None), Crop (DEFAULT.CRO), Soil (DEFAULT.SOL), and Management (Field and Irrigation, both None). The growing period is specified as 'Day 1 after sowing: 10 April - Harvest: 12 August'.
- Simulation panel:** Contains a 'Simulation run' button and a list of simulation parameters: Simulation period, Initial conditions, Display options, and Output files. A 'Display' button is connected to the Output files parameter.
- Navigation:** Includes 'Select or Create soil file' and 'Display/Update Soil Characteristics' buttons.
- Footer:** Features 'Exit Program' and 'Help' buttons.

	File Name	Description
Climate.....	(None)	Specify climatic data when Running AquaCrop
Crop.....	DEFAULT.CRO	could be any crop
Soil.....	DEFAULT.SOL	deep loamy soil
Management		
Field.....	(None)	no specific field management
Irrigation.....	(None)	Rainfed agriculture

FARM INCOME AS A FUNCTION OF APPLIED WATER AND WATER COSTS

Cotton gross margin in Southern Spain under current CAP of the EU



**IF THE SUPPLY IS RESTRICTED
BELOW NORMAL, WHAT WOULD
BE THE OPTIMAL COMBINATION
OF CROPS IN MY FARM?**

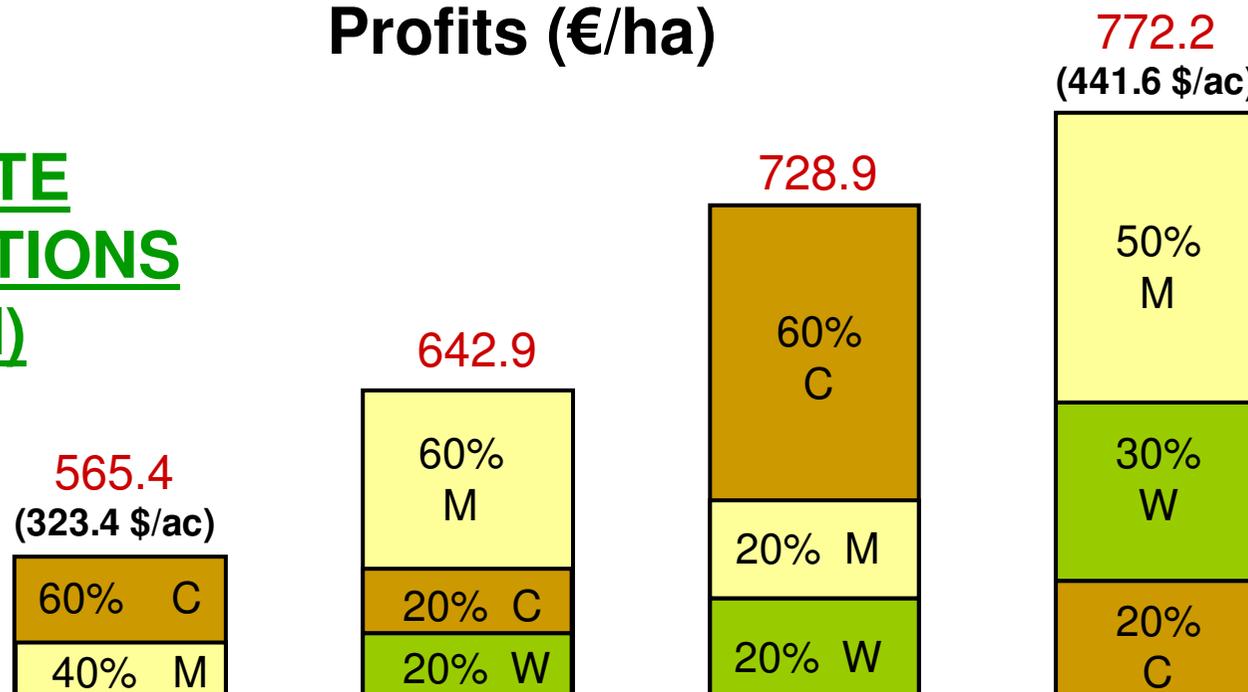




Spain, RDI strategy

Profits (€/ha)

**MODERATE
RESTRICTIONS
(60% of FI)**



Water Allocation: 3000m³/ha (1ac/ft)

Income (FI) (€/ha)

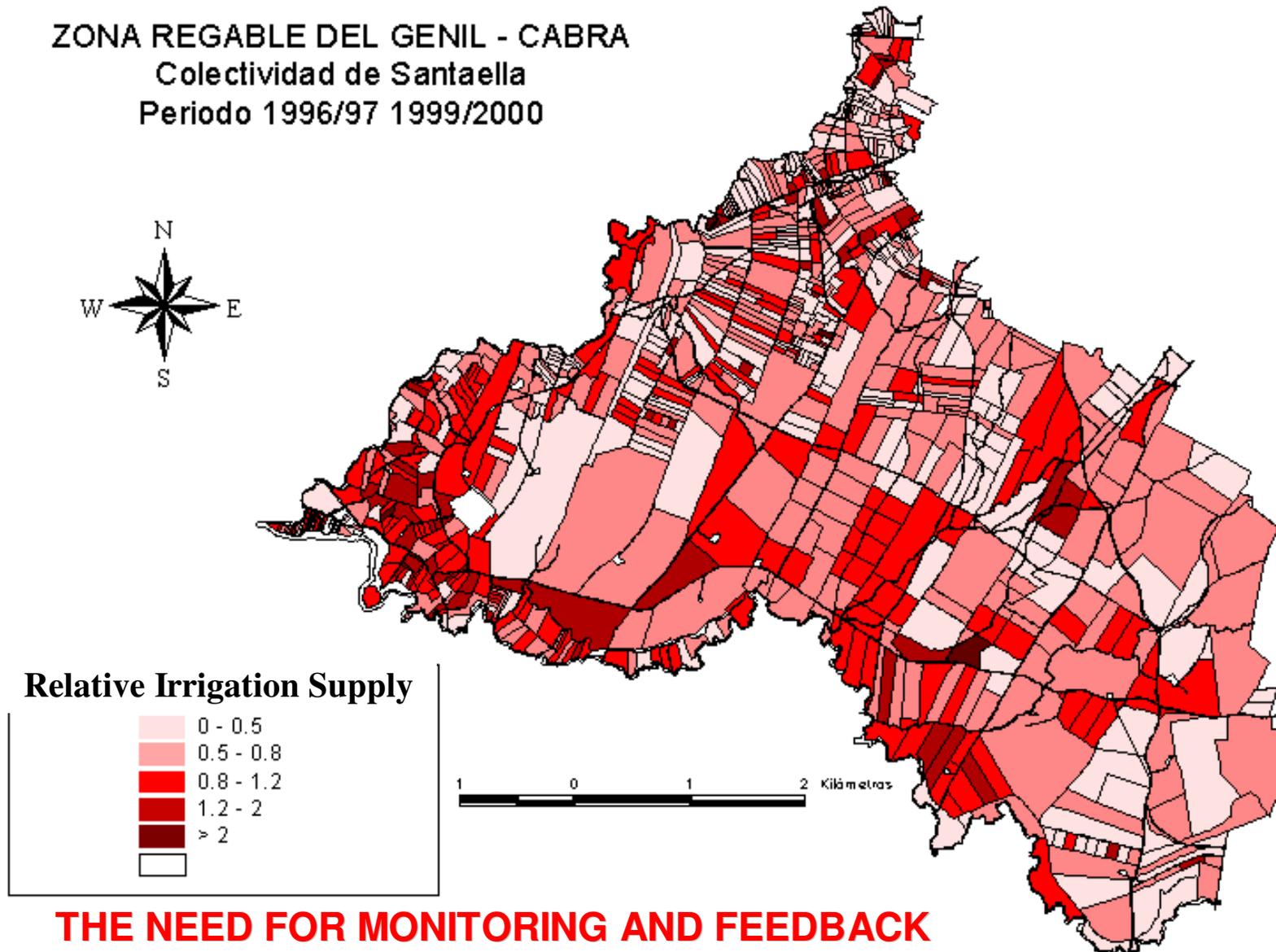
Maize 919.3

Cotton 813.0

Wheat 520.1

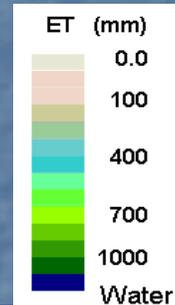
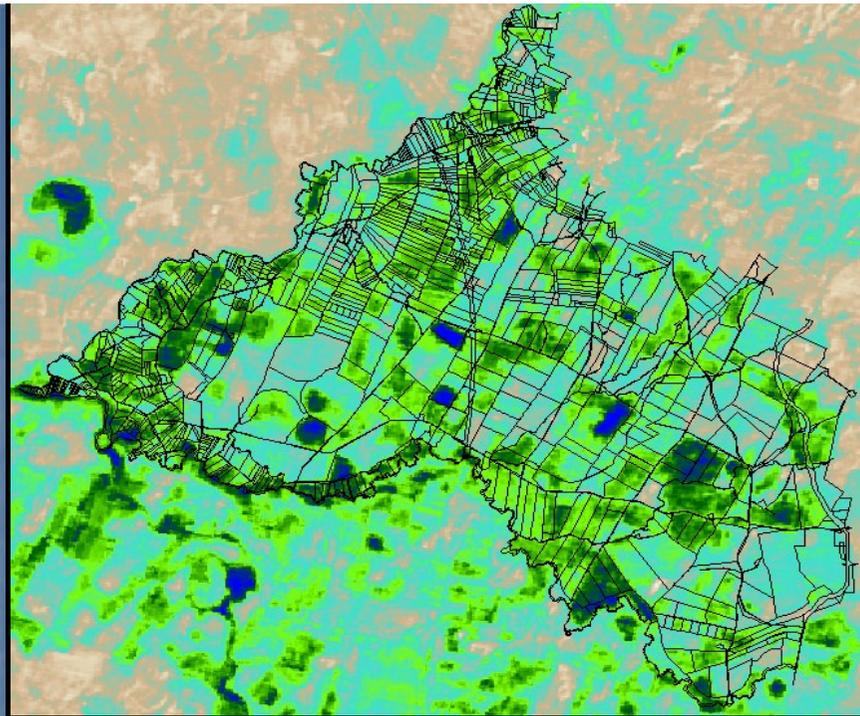
ASSESSING IRRIGATION PERFORMANCE

ZONA REGABLE DEL GENIL - CABRA
Colectividad de Santaella
Periodo 1996/97 1999/2000



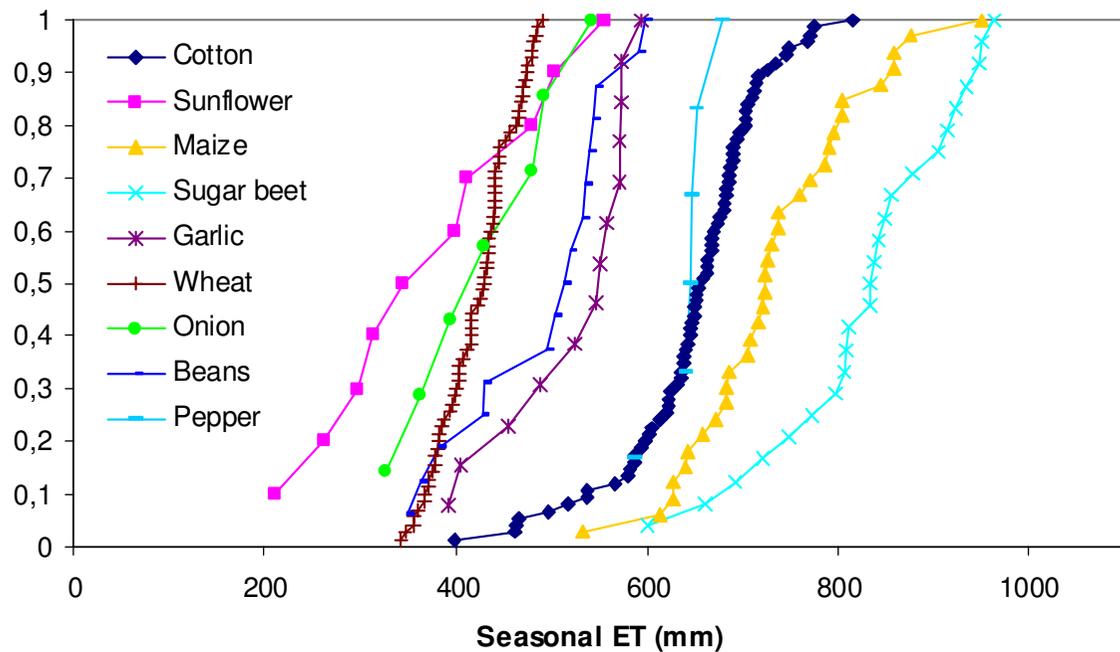
THE NEED FOR MONITORING AND FEEDBACK

(Lorite et al., Irrig.Sci., 2004)



Satellite-based estimation of consumptive use (ET) for planning and for performance assessment. (SEBAL, METRIC, etc.,)

Large variations in Crop ET among farms



**Limitations of satellite imagery:
Time interval (every 14 days), problems with
thermal sensors, pixel size, etc..**

**Goal: monitoring irrigation management
and providing advice**

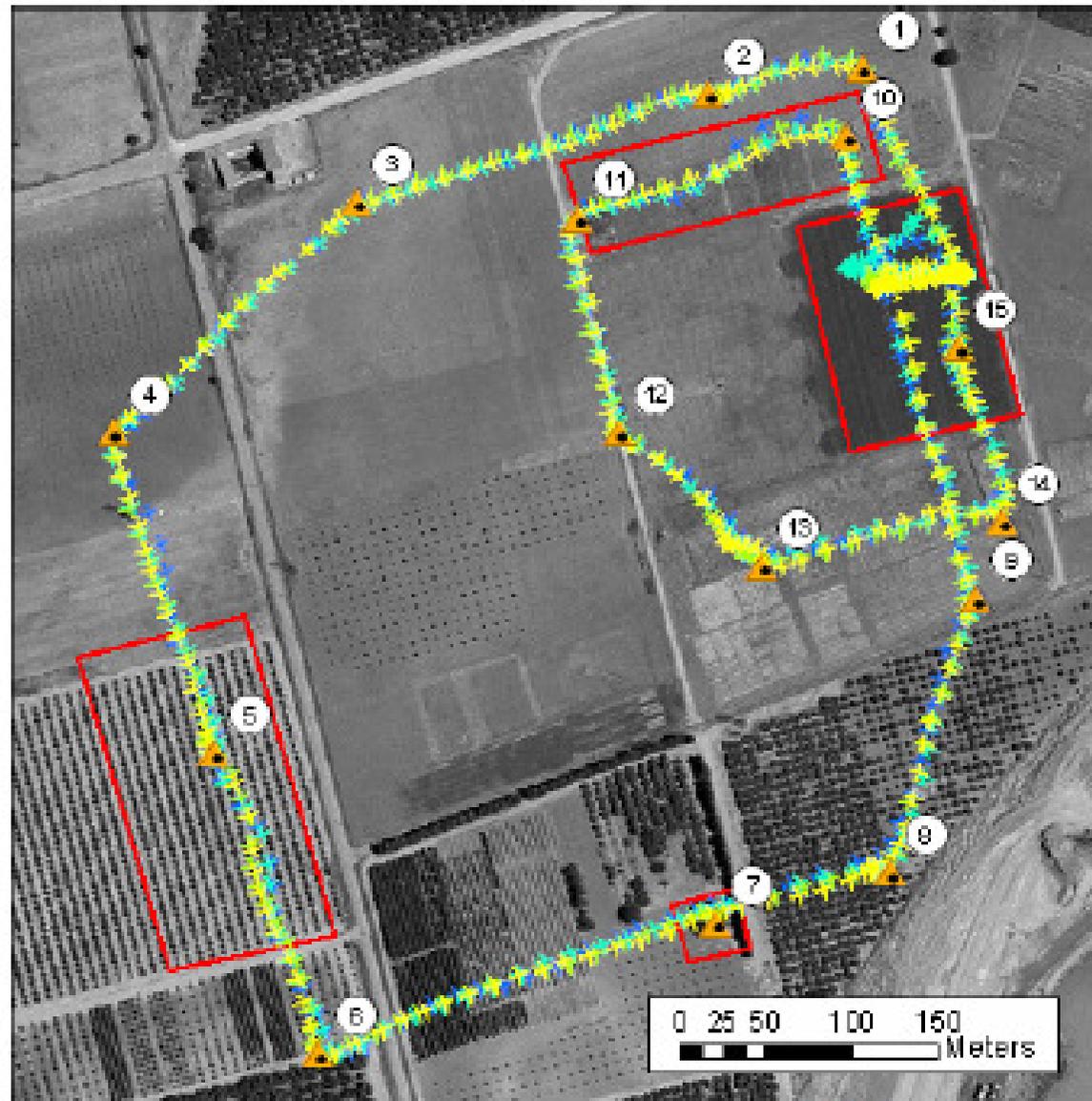




**P. Zarco's team, IAS,
Córdoba.**

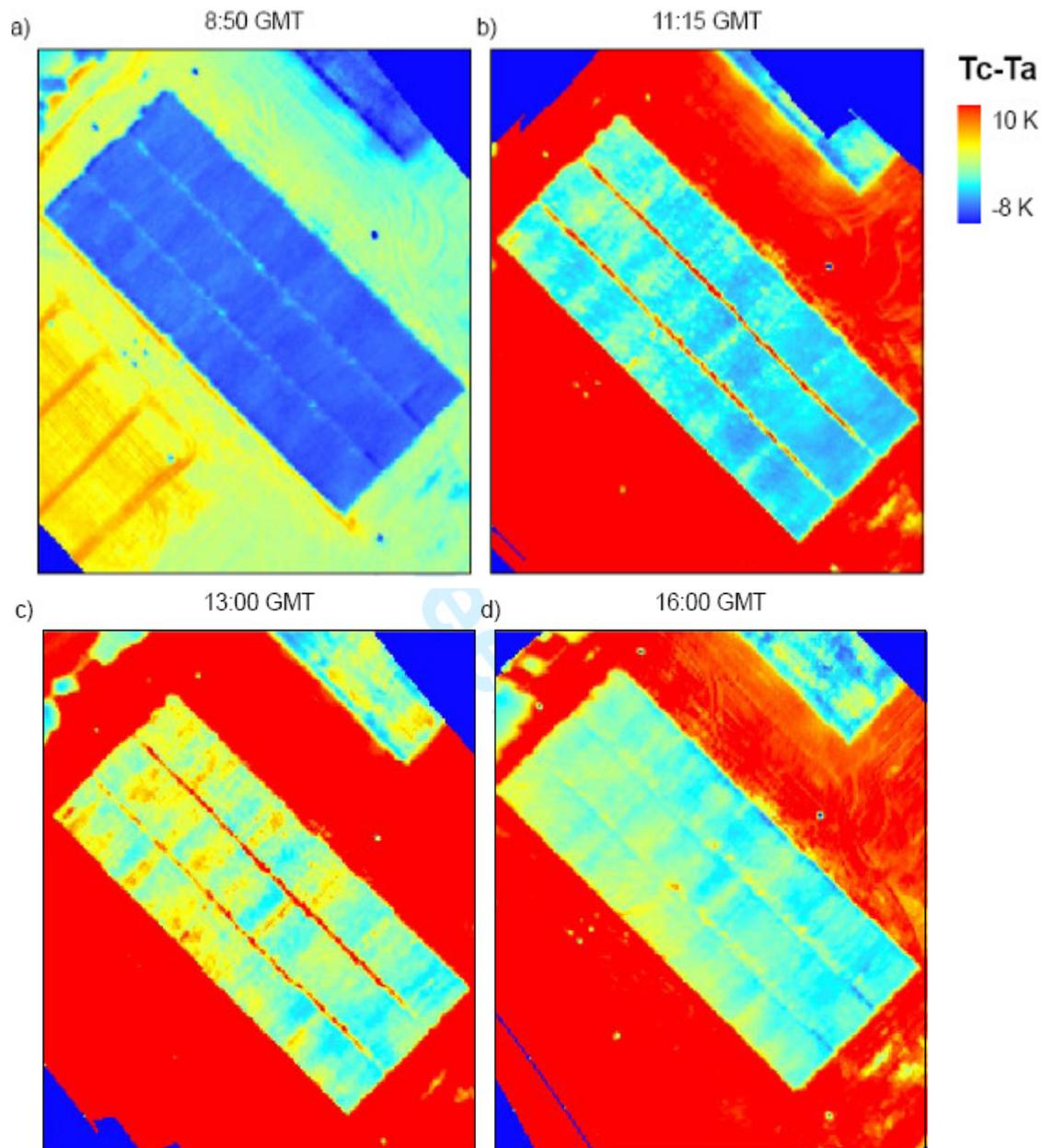


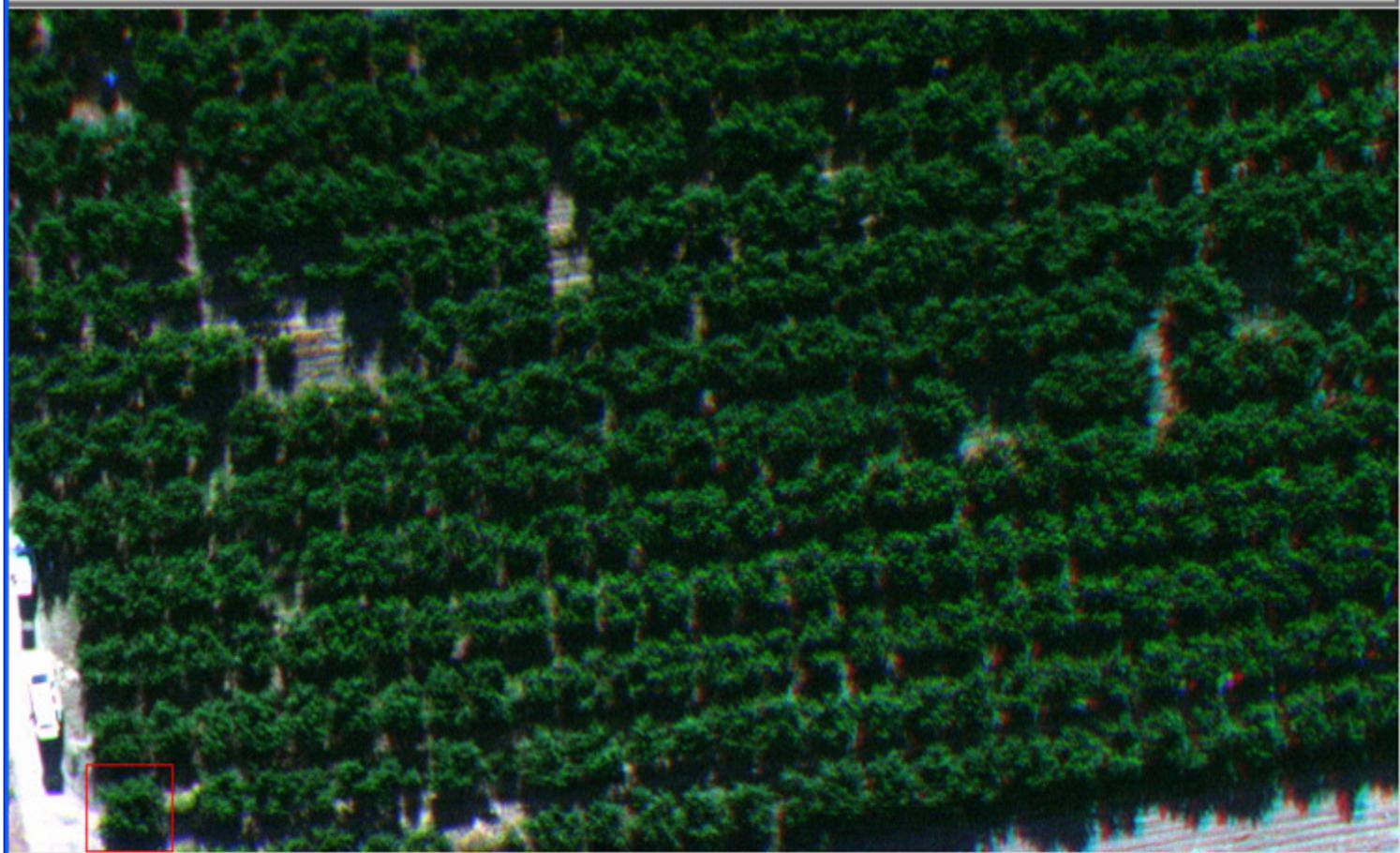




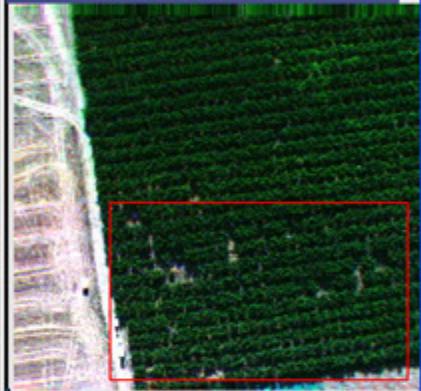
-  Waypoints
-  Study Sites
-  12:15
-  13:35
-  14:10
-  14:50

Flights over a field of 30 maize cultivars replicated three times, showing images of canopy temperature differential where variations among cultivars are detected prior to irrigation

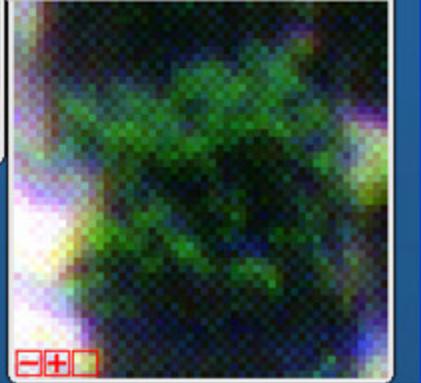




#1 Scroll (0.20000)

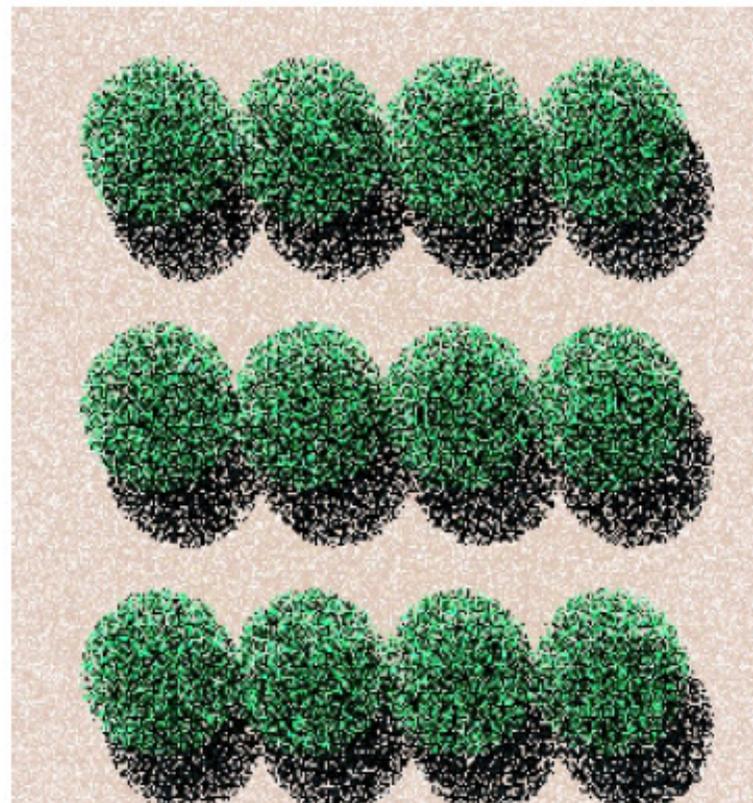
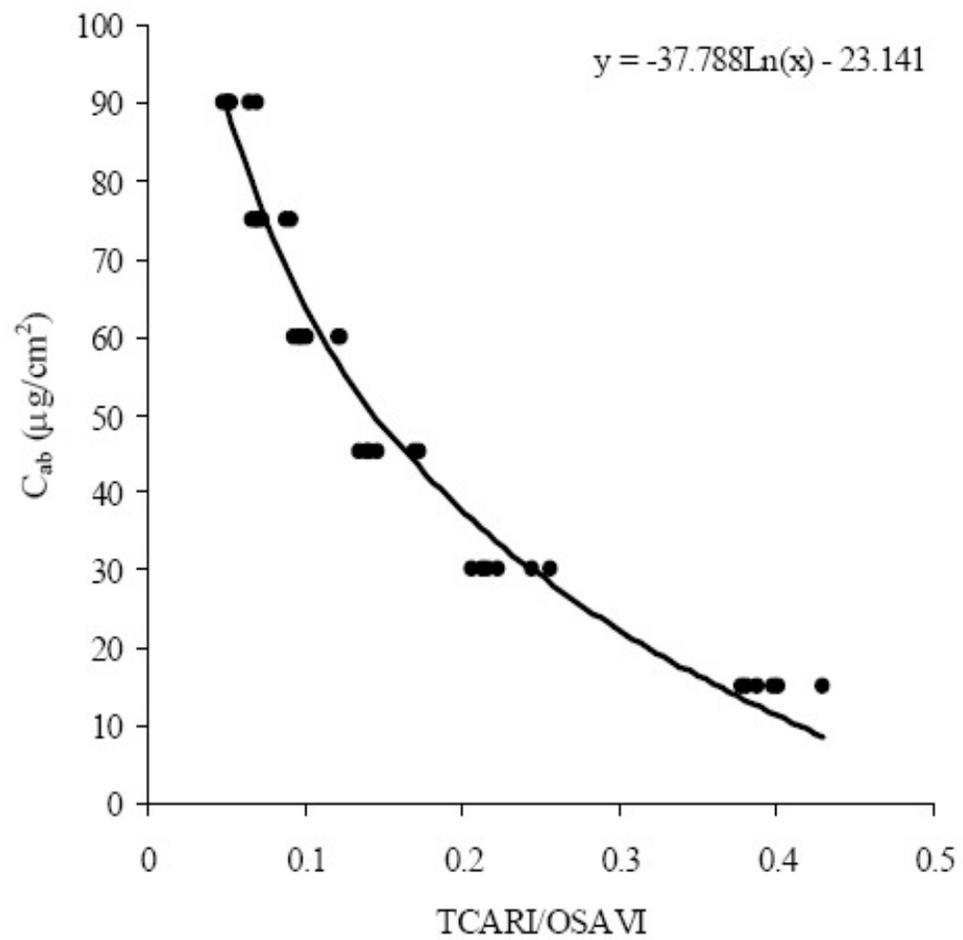


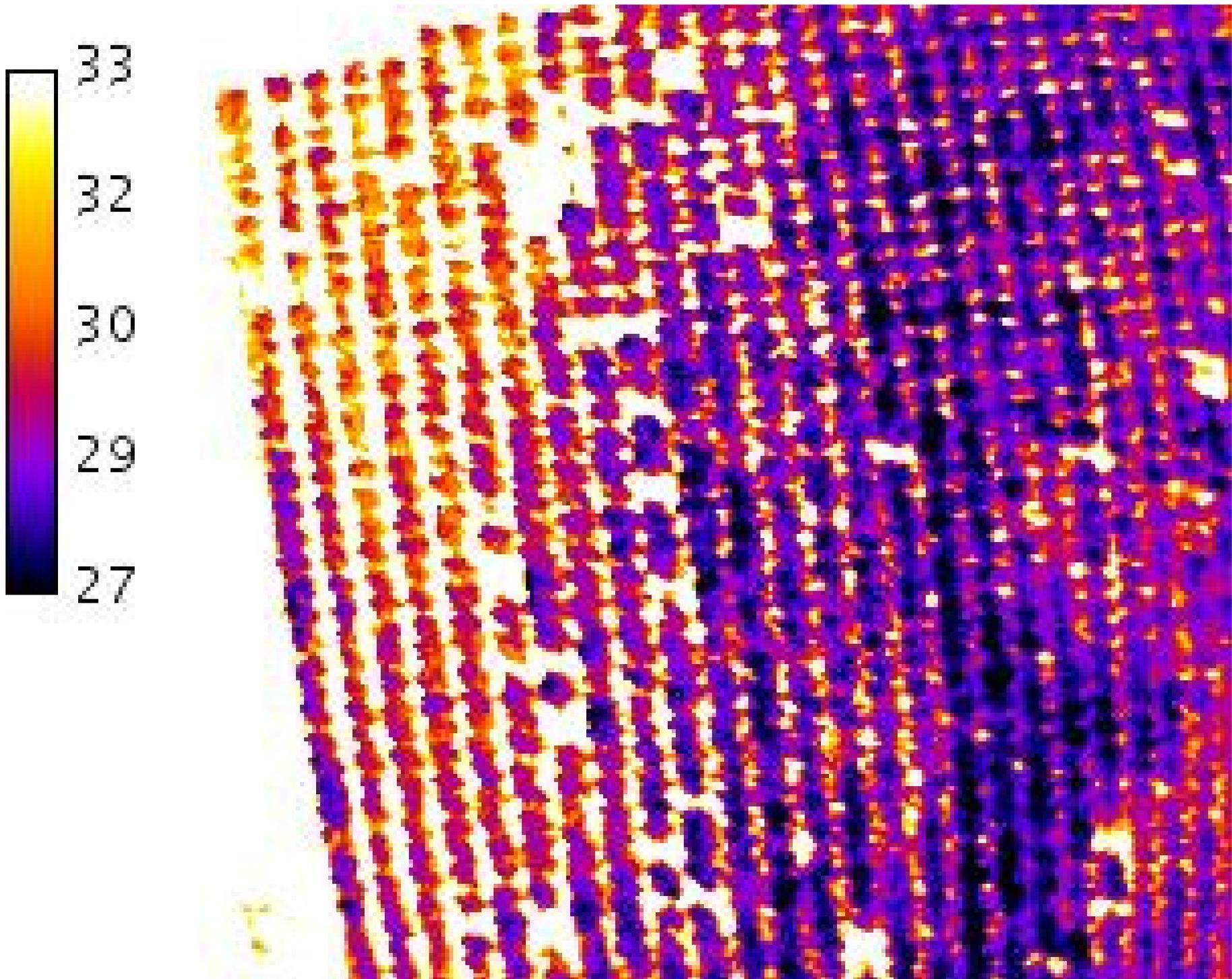
#1 Zoom [4x]



Dims 1280 x 1024 (Integer) [BSQ]

Load RGB Display #1▶

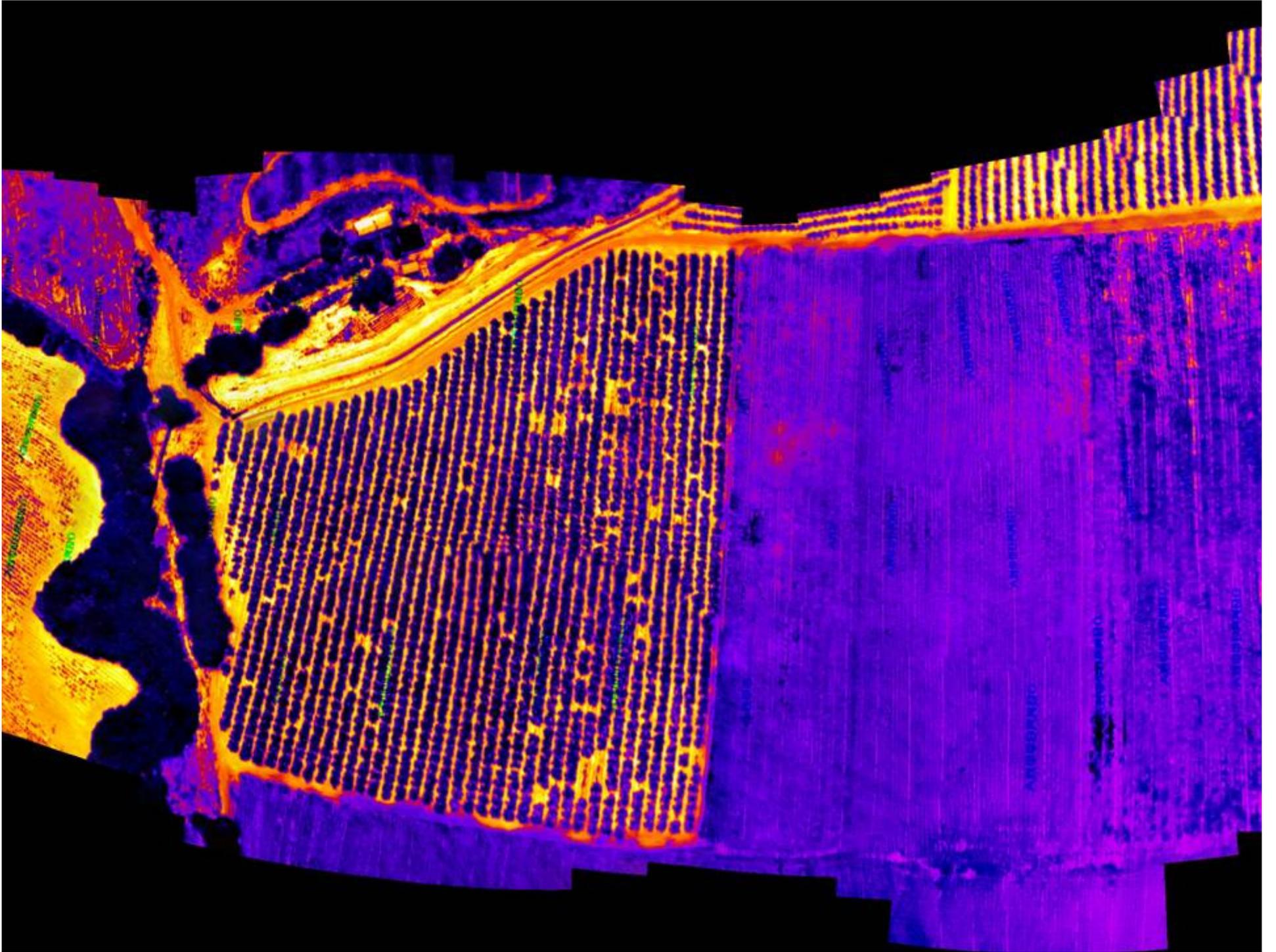




**IN CONCLUSION,
FROM RESEARCH TO ACTION**









(K. Sayre, CIMMYT)