Management of Water and Nutrients for Young Olive Trees

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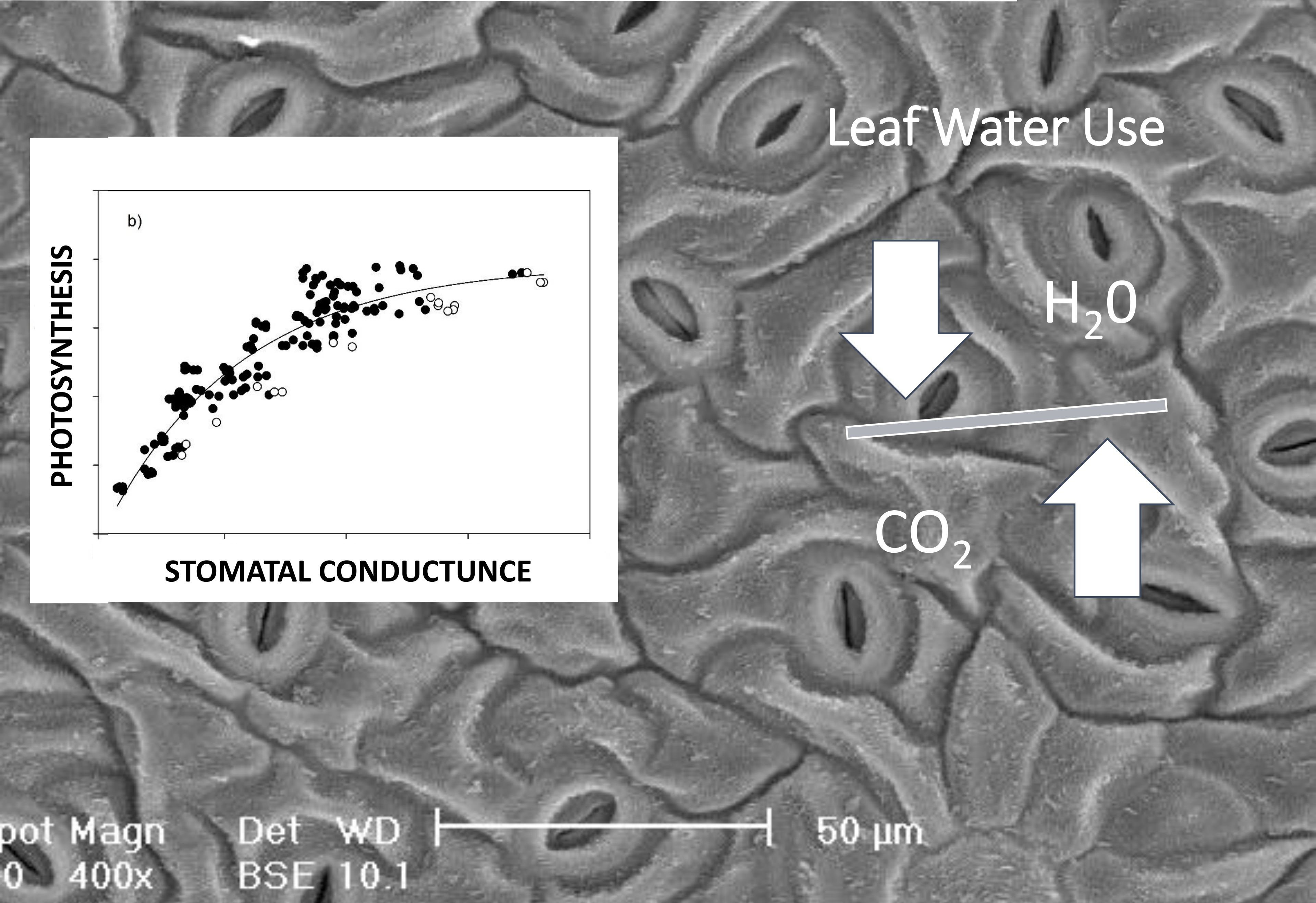
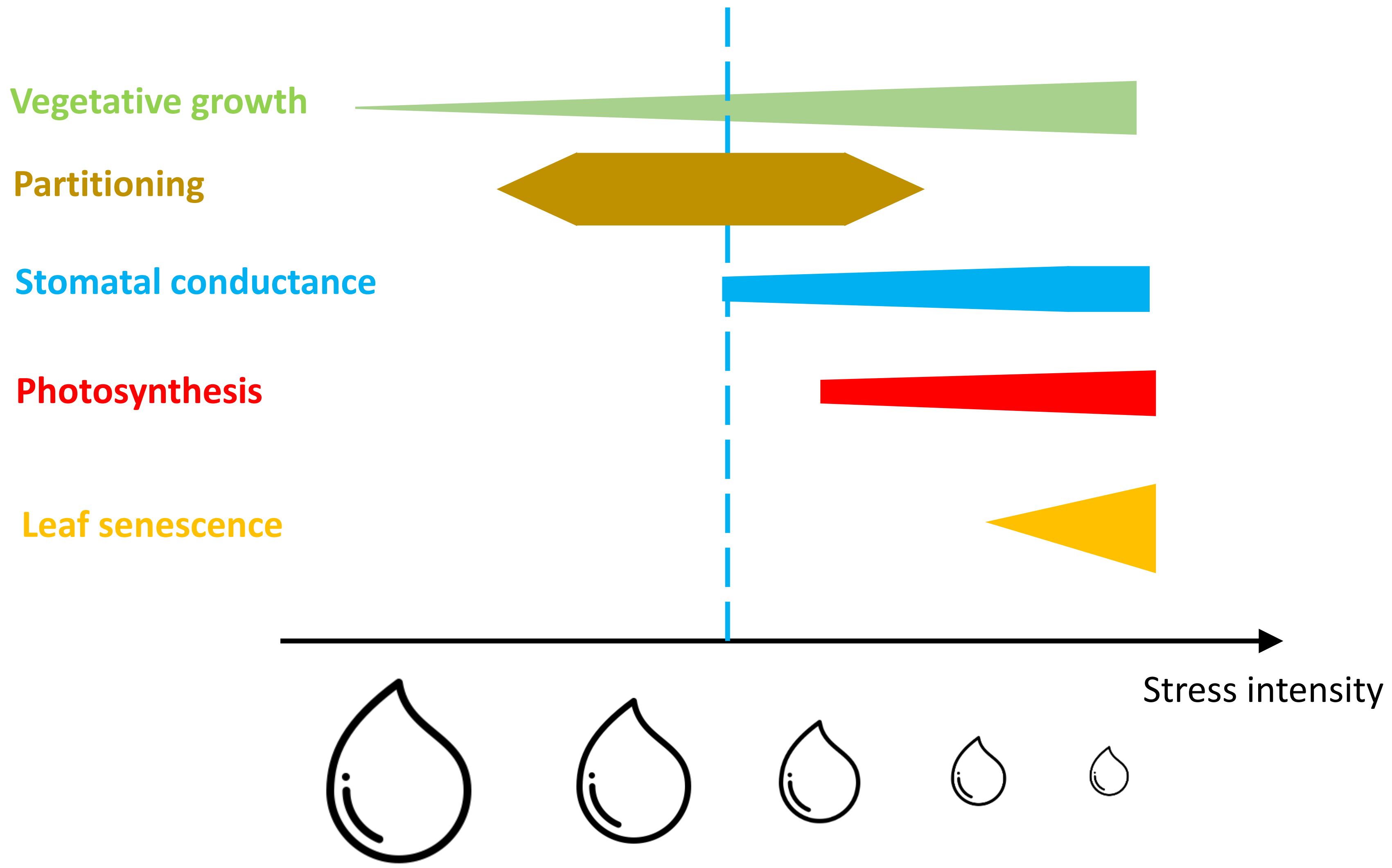
Outline

- Why we irrigate
- Crop evapotranspiration
- Water stress in olive
- Plant monitoring
- Fertilization

Irrigation objectives

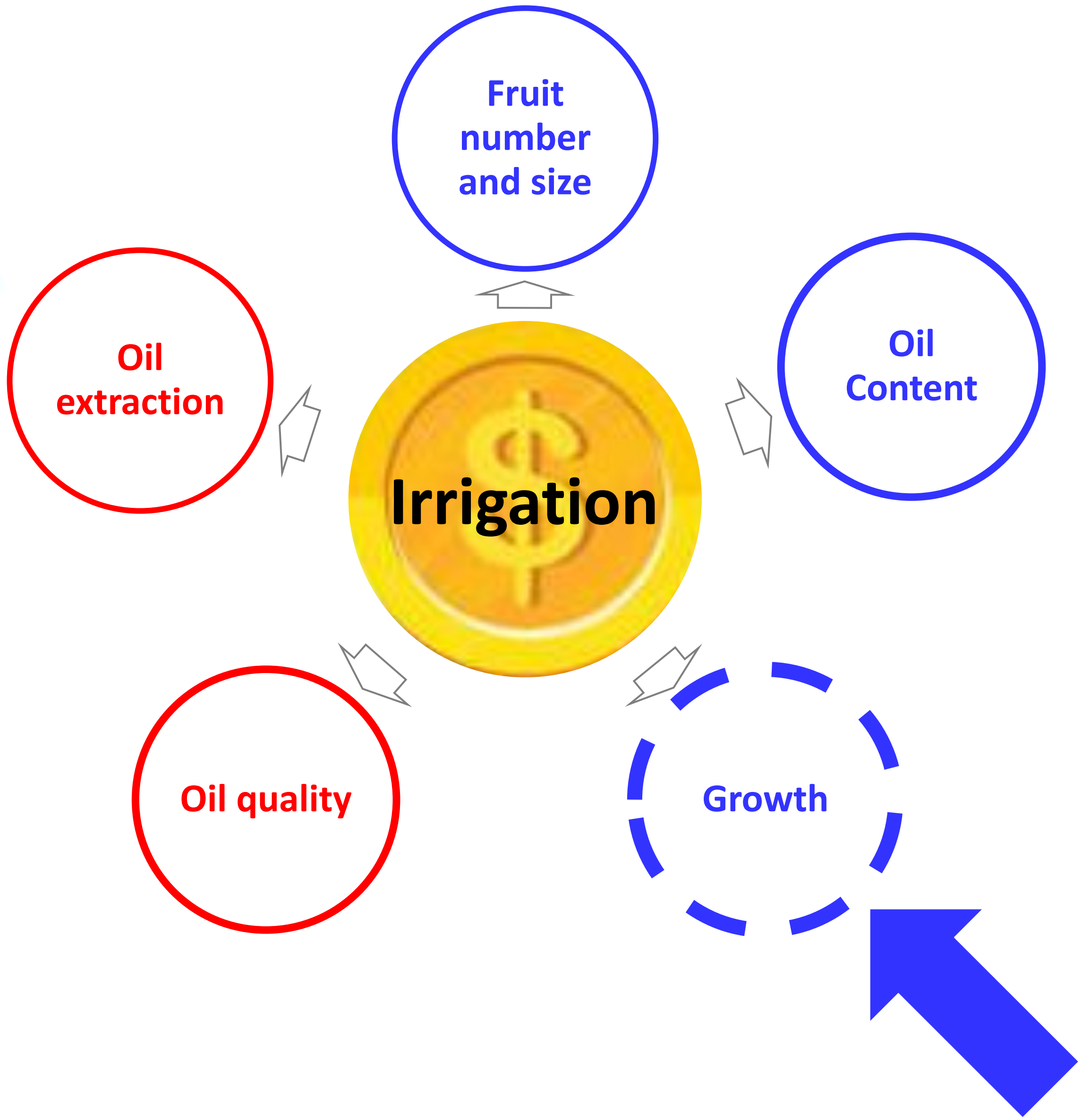


Effect of drought on tree physiology



Bradford and Hsiao, 1982

Why We Irrigate?



No stress in young olive: objective is fast growth

- Frequent irrigation
- No soil saturation – olive sensitive to asphyxia
- Trees with very small root system
- Previously to winter, reduce irrigation to promote hardening and reduce risks of freeze damage

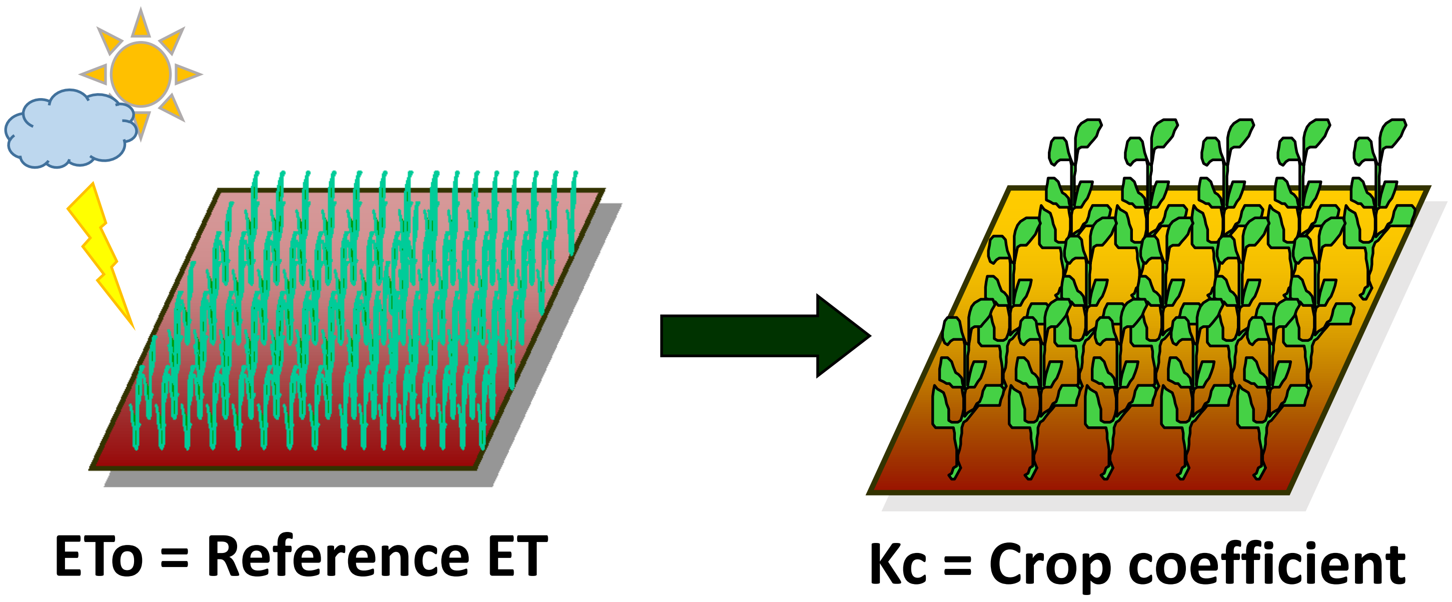
Irrigation methods

- ET
- Soil monitoring
- Plant monitoring

Estimate crop evapotranspiration

$$ET_c = ET_o \times K_c$$

- ET_o accounts for weather factors
- K_c accounts for crop differences



Crop Evapotranspiration (ETc)

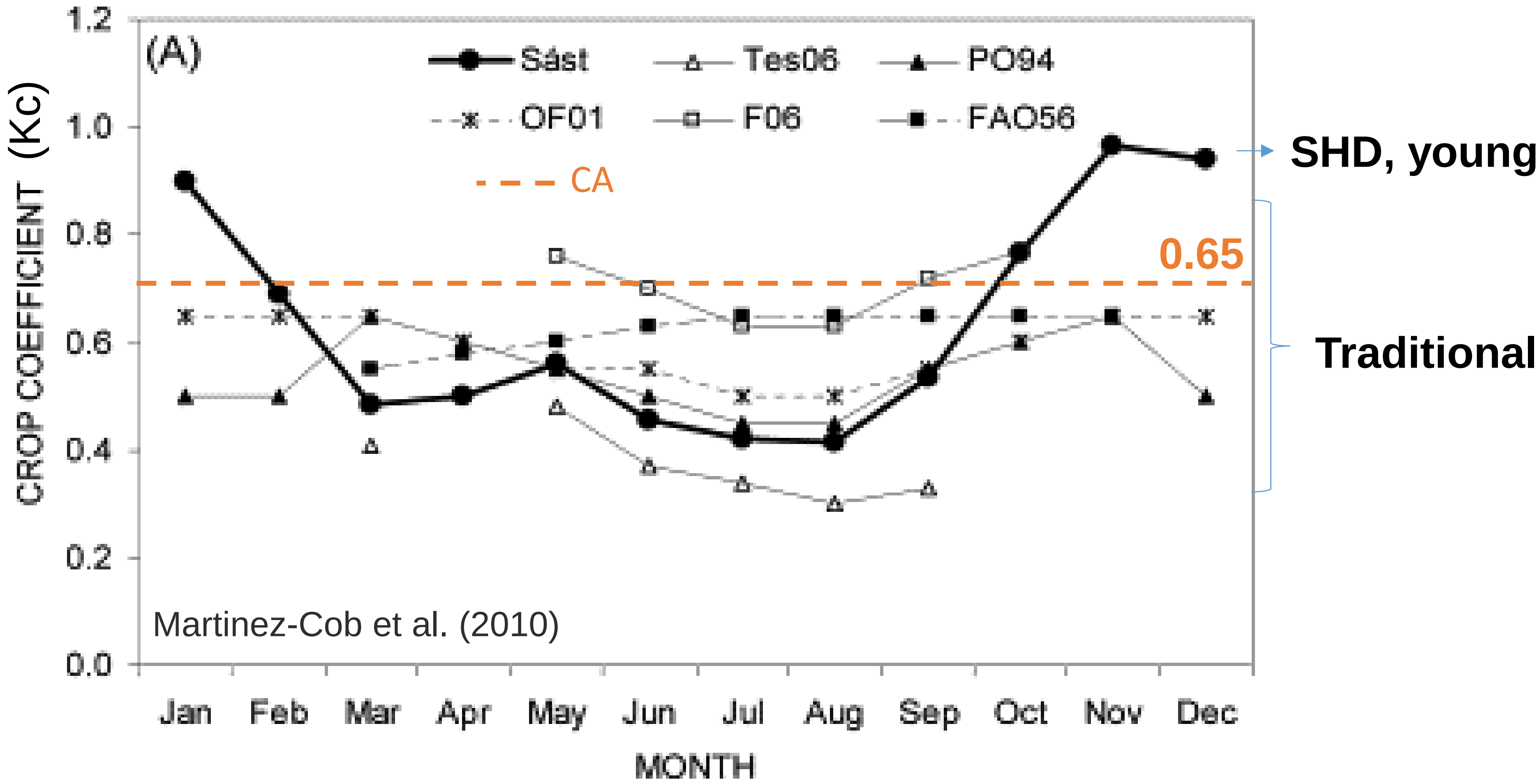
$$ETc = ETo \times Kc \; (\times Kr)$$

Month	ETo* (in)	*Kc*†	ETc (in)	ETc (in/day)
Jan	1.6	0.65	1.0	0.03
Feb	2.2	0.65	1.4	0.05
Mar	3.7	0.65	2.4	0.08
Apr	5.1	0.65	3.3	0.11
May	6.8	0.65	4.4	0.14
Jun	7.8	0.65	5.1	0.17
Jul	8.1	0.65	5.3	0.18
Aug	7.8	0.65	5.1	0.16
Sep	5.7	0.65	3.7	0.12
Oct	4.0	0.65	2.6	0.08
Nov	2.1	0.65	1.4	0.05
Dec	1.6	0.65	1.0	0.03
Total	57.0		37.0	

1.26 in per week

Mature Olive Crop Coefficient (Kc)

ETc = Kc x ETo



Kc in CA for olive **0.65**. Developed in spaced (5 x 9 m), vase-shaped Manzanillo orchards, some flood-irrigated. Goldhamer et al. (1994)

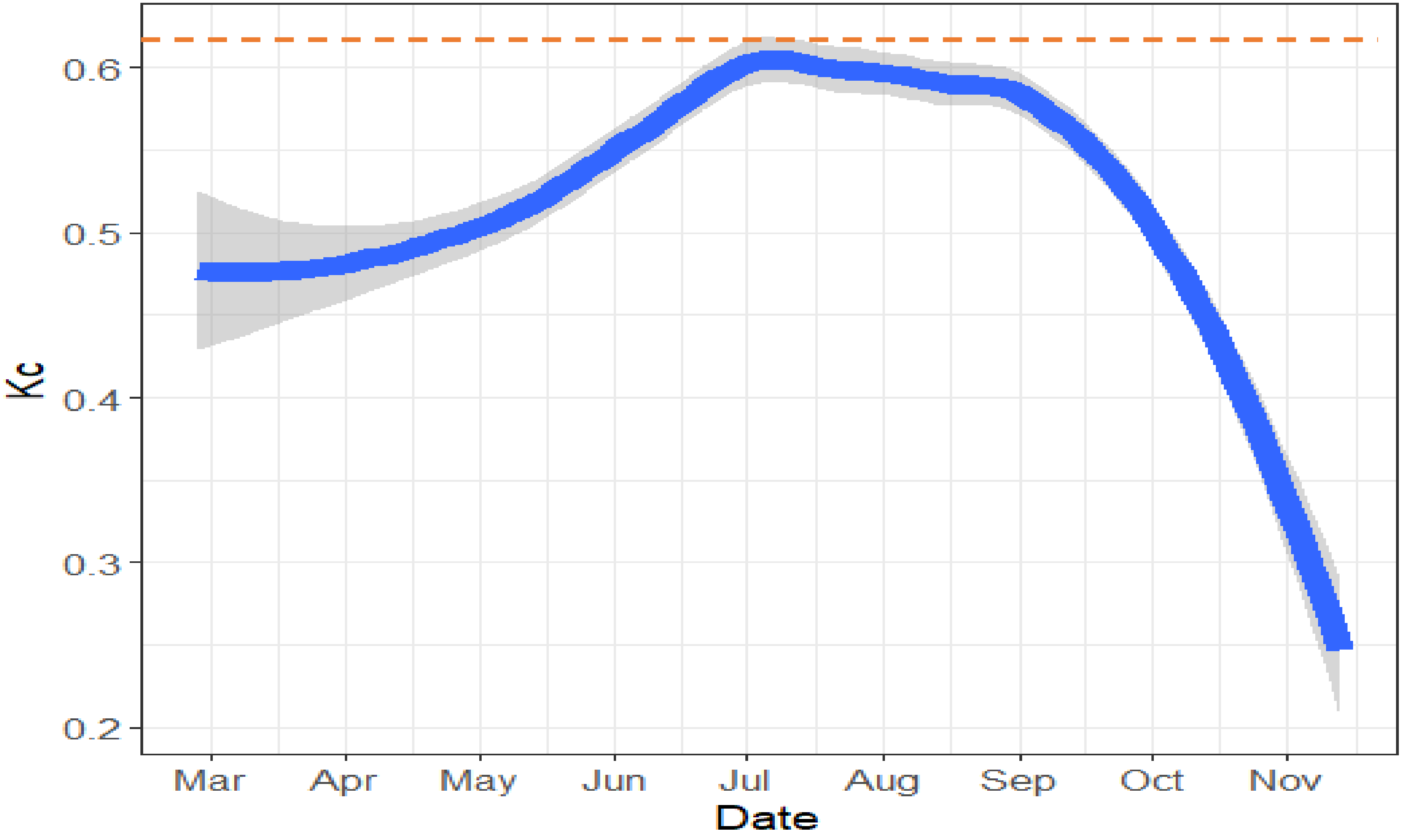
Methods

RESIDUAL OF ENERGY BALANCE WITH EDDY COVARIANCE

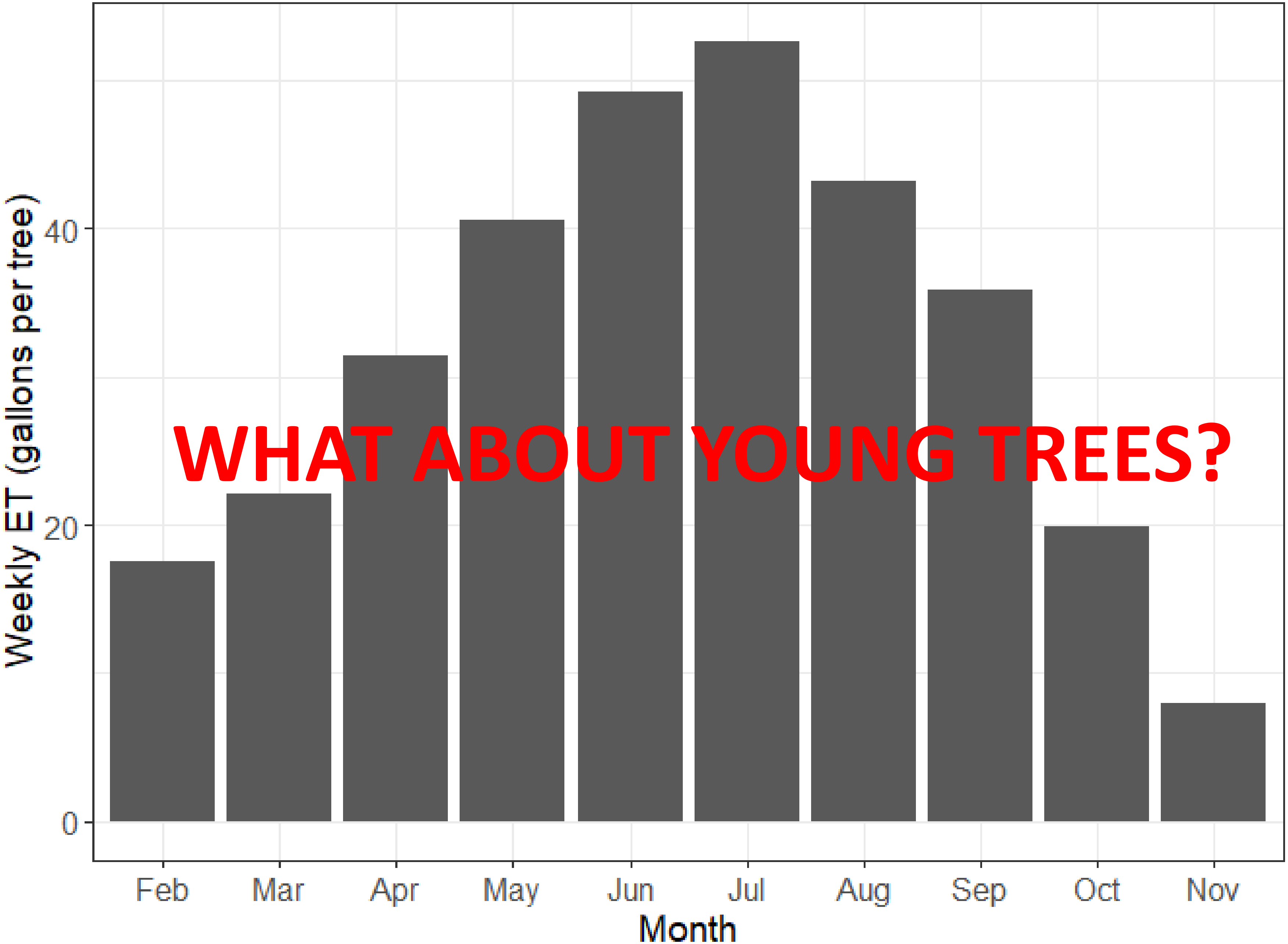
$$LE = Rn - G - H$$

MIDDAY STEM WP WITH PRESSURE BOMB

Evapotranspiration and Crop Coefficients



The Kc in spring was lower than what suggested in literature


WHAT ABOUT YOUNG TREES?
Weekly ET (gallons per tree)
40
20
0
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Month

Adjustment for site specific conditions

$$ETc = ETo \times Kc \times Kr$$

Kr = Reduction coefficient for orchards with canopies shading less than 60% of the ground

$Kr = 2 \times fc$

fc = The fraction of ground shaded by olive trees at midday

For round shaped canopies:

$fc = (\pi \times D^2 \times N) \div 174{,}240$

D (ft) = average diameter of the canopy
N = the number of trees per acre

Fereres et al 1982

Adjustment for site specific conditions

$$ETc = ETo \times Kc \times Kr$$

Kr = Reduction coefficient for orchards with canopies shading less than 60% of the ground

$Kr = 2 \times fc$

fc = The fraction of ground shaded by olive trees at midday

For hedgerow systems:

$fc = (N \times d \times r) \div 43{,}560$

N = number of trees per acre
D (ft) = average width of the canopy
r (ft) is the distance between trees

Fereres et al 1982

Water stress in olive

Increased water stress

How to measure stress

Plant Monitoring: observation

Plant water potential

The tool: Pressure bomb

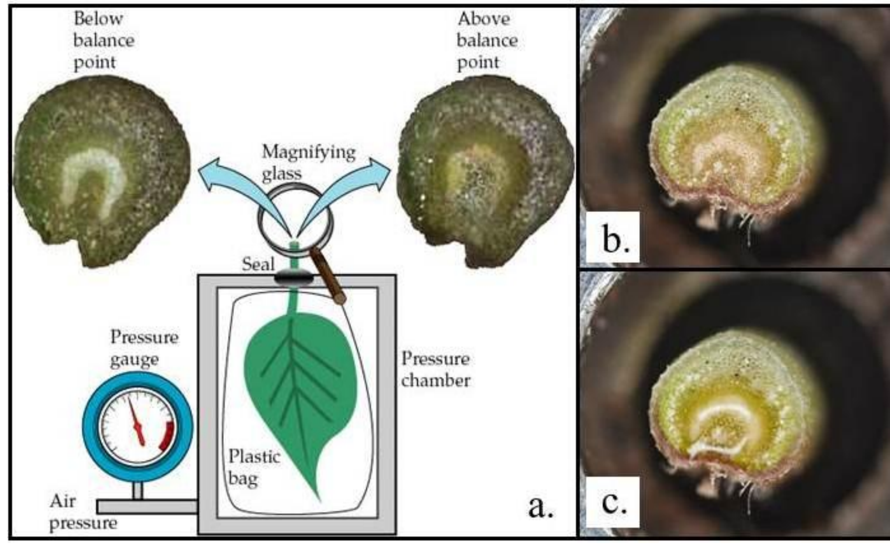
Sealed chamber

Manometer

Valve

Pressurized gas tank

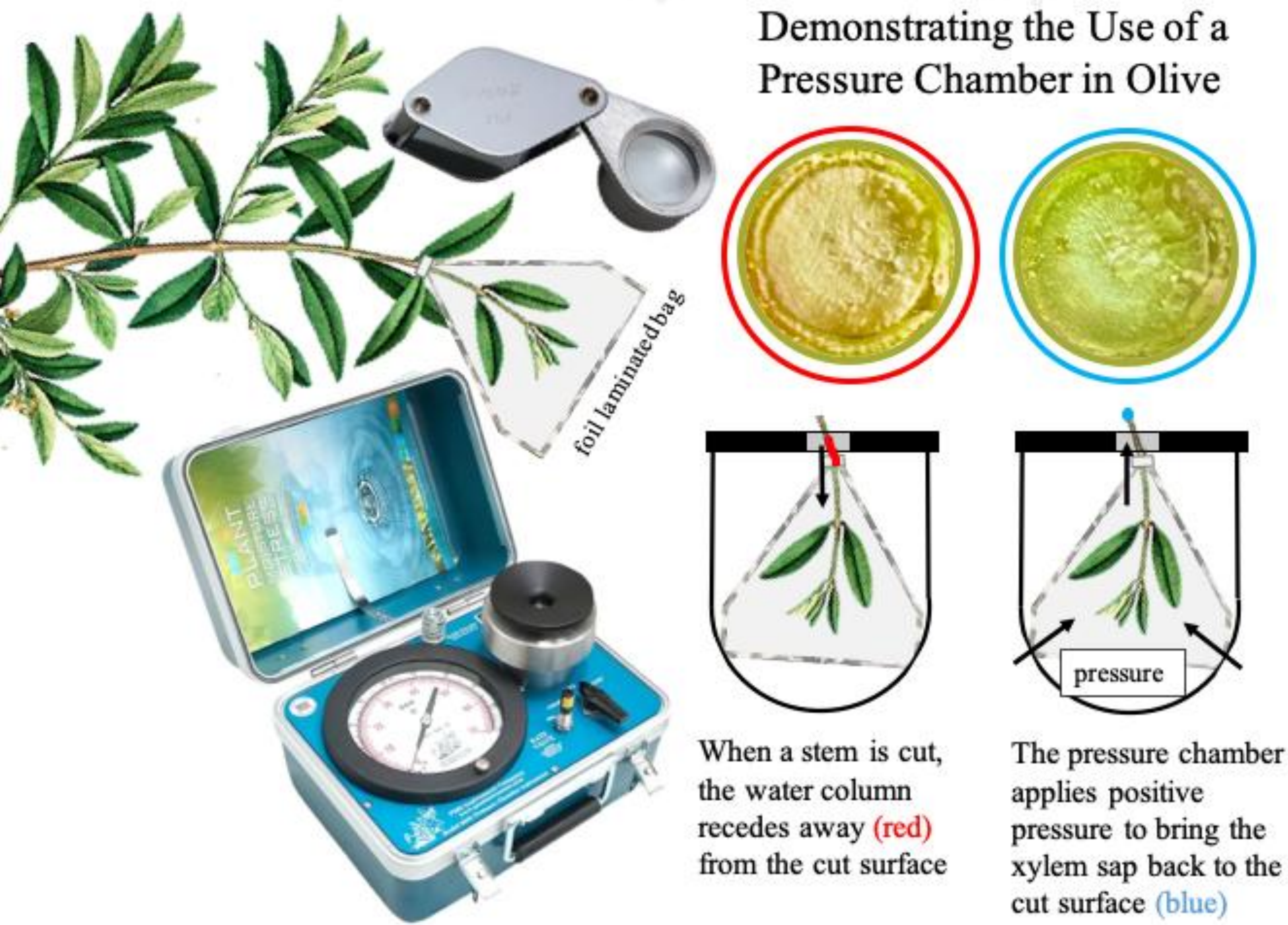
The indicator: midday stem water potential (SWP)



-12 bar

Pressure is <u>equal and opposite</u> to the water potential of the sample

< water in the plant = > energy needed to force it outside = > the pressure in the chamber


Demonstrating the Use of a
Pressure Chamber in Olive
foil laminated bag
pressure
When a stem is cut, the water column recedes away (red) from the cut surface
The pressure chamber applies positive pressure to bring the xylem sap back to the cut surface (blue)

Physiological thresholds

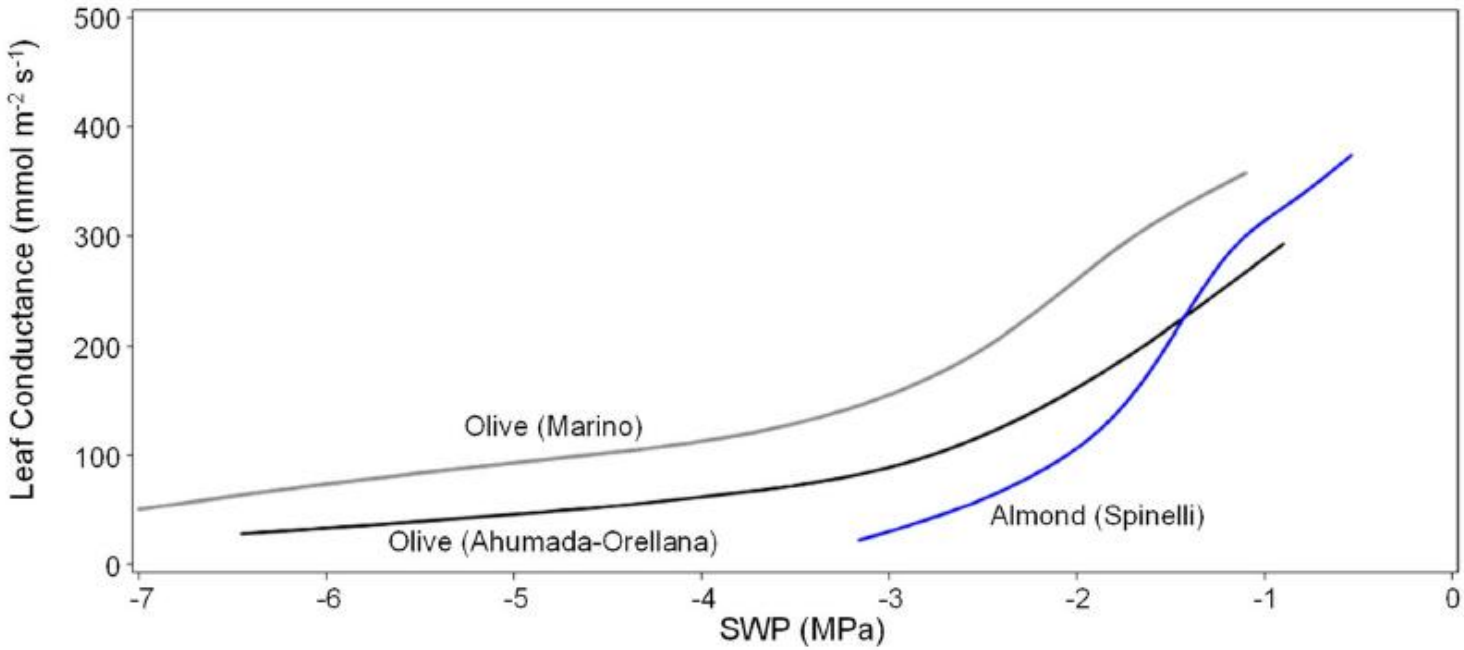


FIGURE 7 | Relation of leaf conductance to SWP for almond reported by Spinelli et al. (2016), for olive reported by Marino et al. (2018), and for olive reported by Ahumada-Orellana et al. (2019). Each line is a 60% smoothed spline function fit to the raw data (Proc Transreg SAS 9.4).

Shackel et al 2021

TREE SYSTEMS LAB

UC DAVIS

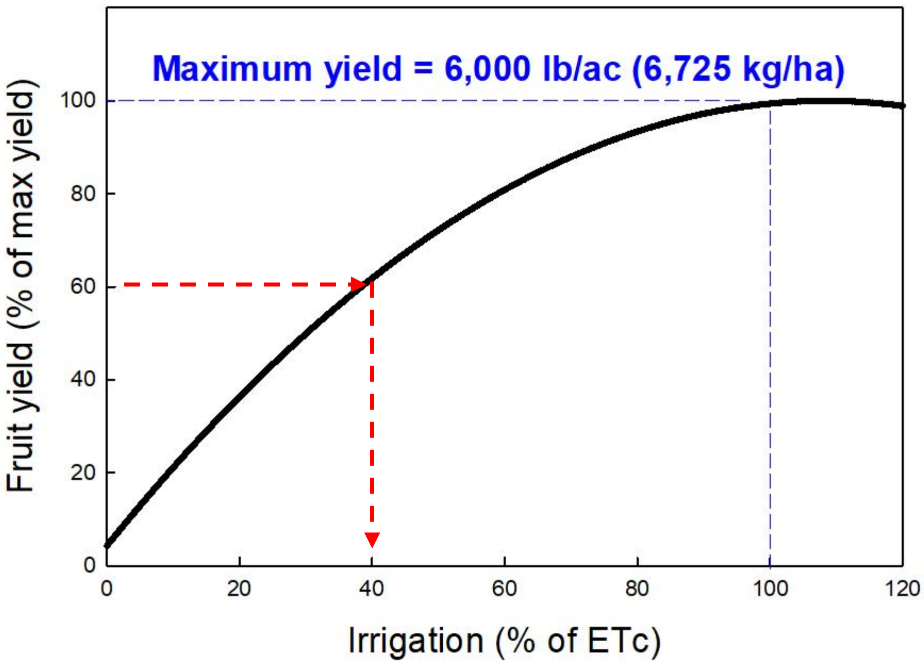
Plant monitoring: water potential baseline

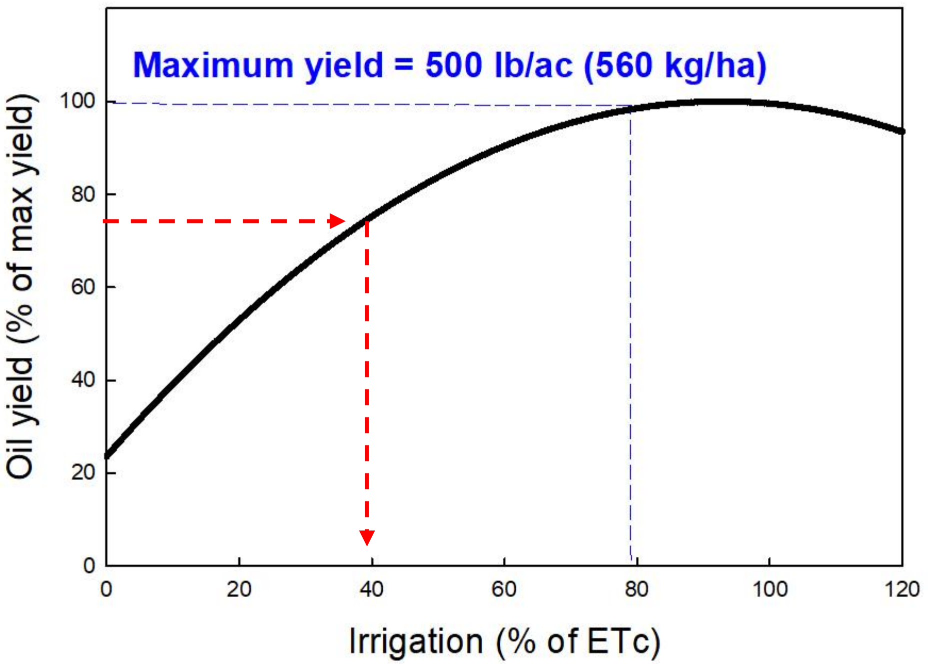
Milliron et al. 2022

	Relative Humidity (%)								
Temperature (F)	25%	30%	35%	40%	45%	50%	55%	60%	65%
70°	-11	-11	-11	-11	-11	-11	-11	-10	-10
75°	-12	-12	-12	-12	-11	-11	-11	-11	-10
80°	-13	-13	-12	-12	-12	-11	-11	-11	-11
85°	-13	-13	-13	-12	-12	-12	-12	-11	-11
90°	-14	-14	-14	-13	-13	-12	-12	-12	-11
95°	-15	-15	-15	-14	-14	-13	-13	-12	-12
100°	-16	-16	-15	-15	-14	-14	-13	-13	-12
105°	-18	-17	-16	-16	-15	-15	-14	-14	-13

Stem water potential values for non stressed trees (change with environment)

Sustained Deficit irrigation: yield

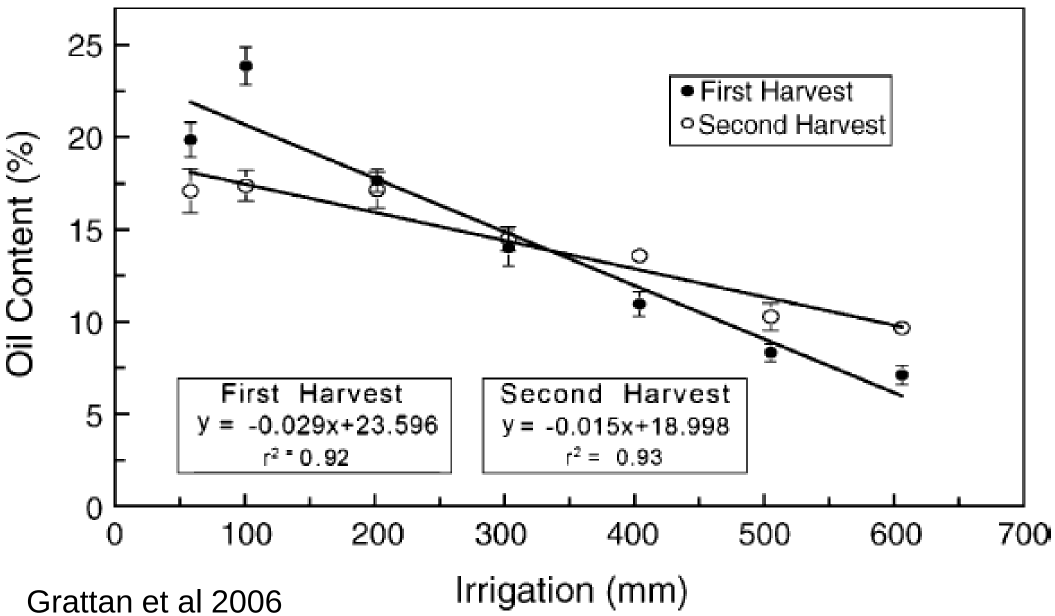




Modified from Grattan et al 2006 – Olive Manual (under press)

100% oil yield with 80% of ET

Sustained deficit irrigation: yield parameters



Grattan et al 2006

ET (%)	Polyphenols (mg/kg)
16	175.1
21	121.2
41	91.5
62	62.5
83	48.9

Marra et al. 2016

Irrigation at 33 to 40 percent ETc produced oils with more balanced organoleptic profiles—with higher but not excessive levels of bitterness and pungency, and higher fruitiness and other appealing flavors—and may be appropriate if oil quality is the grower's main objective (Berenguer et al. 2006).

Regulated Deficit irrigation

Planned water deficits at specific crop developmental stages that control vegetative growth or improve quality without negatively affecting production

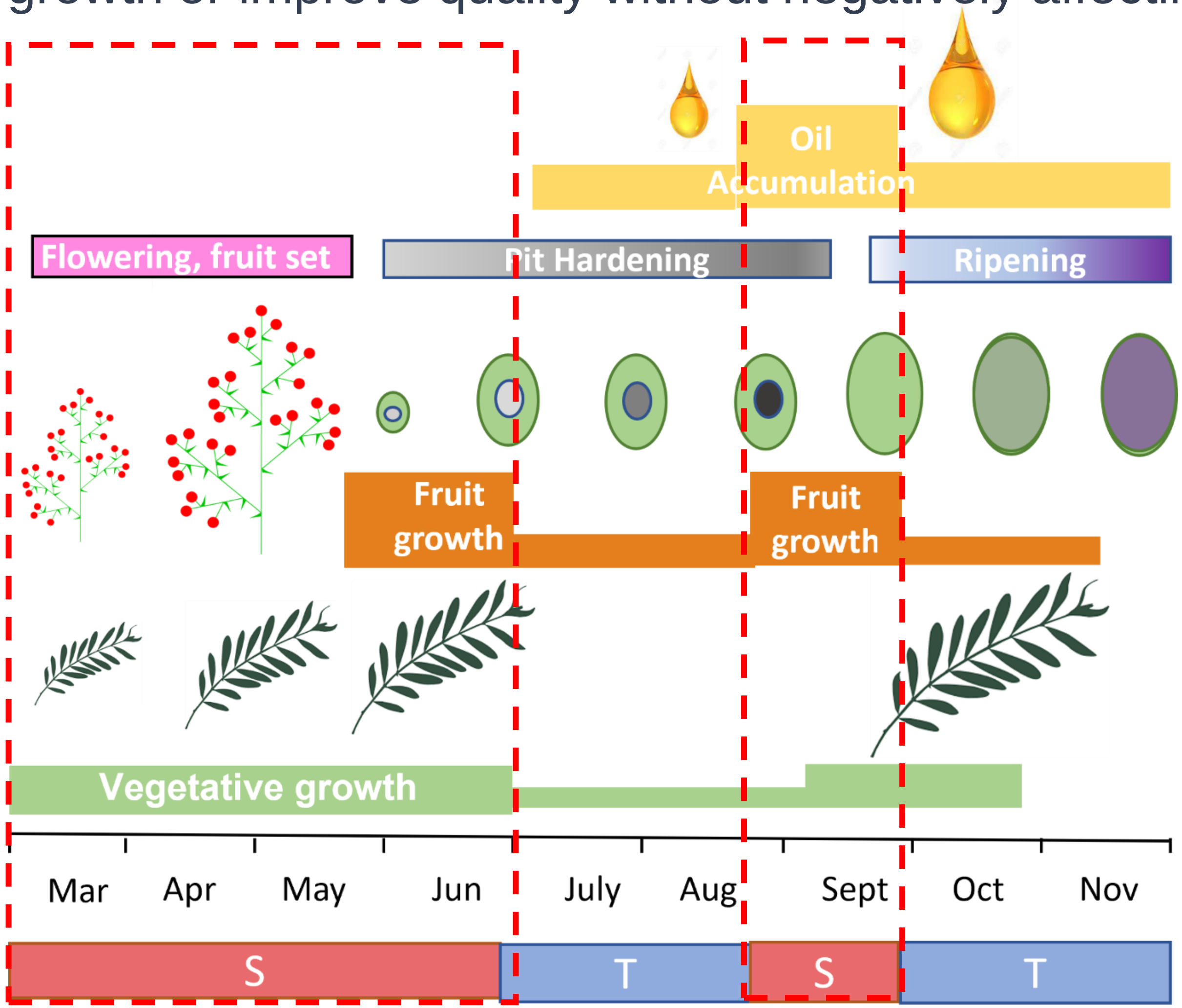
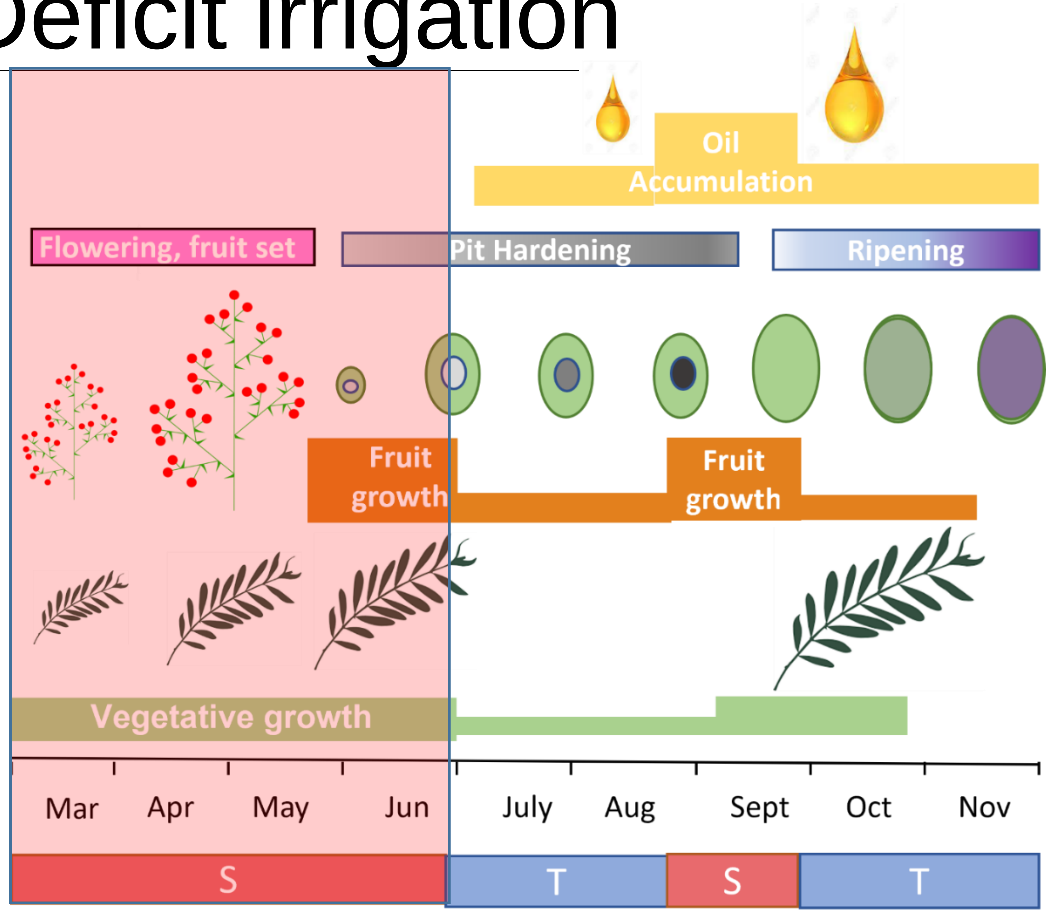


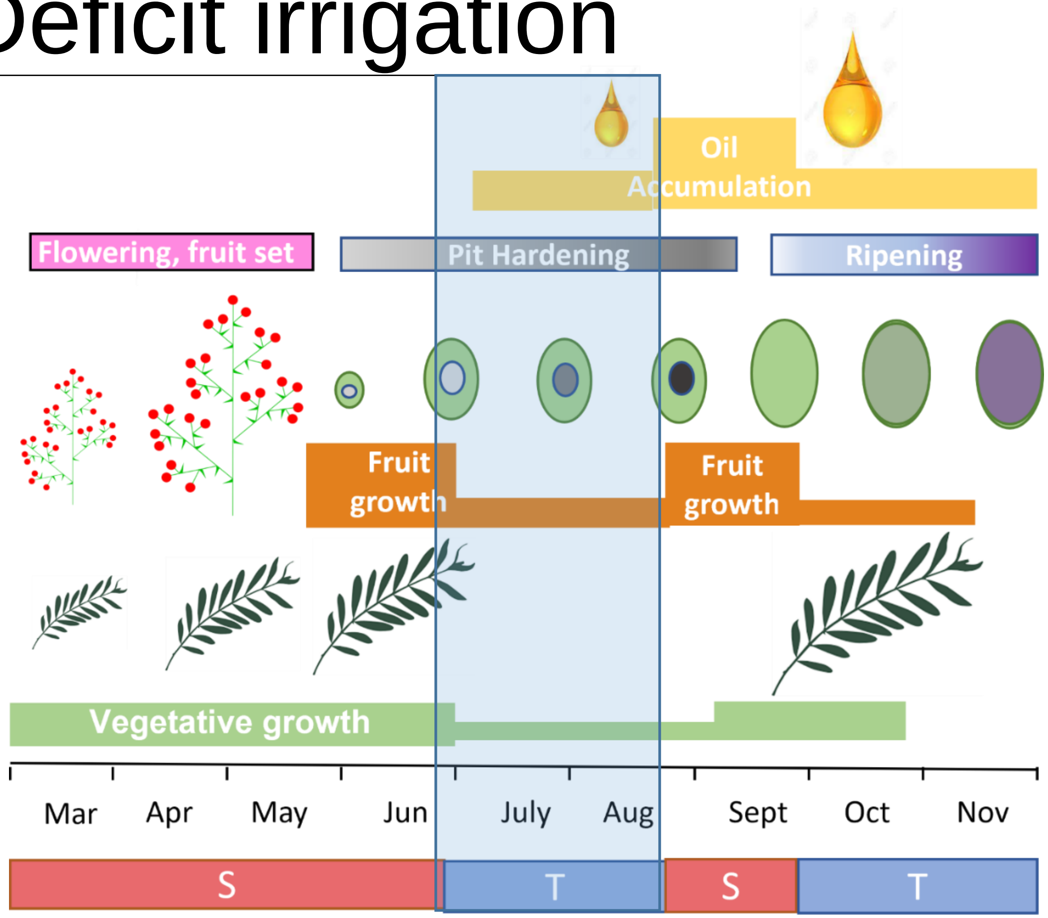
Figure from the new olive Manual (in press), adapted from Fernández 2017; Fernández et al. 2013; Fernández et al. 2018; Hernandez-Santana et al. 2017.

Regulated Deficit irrigation



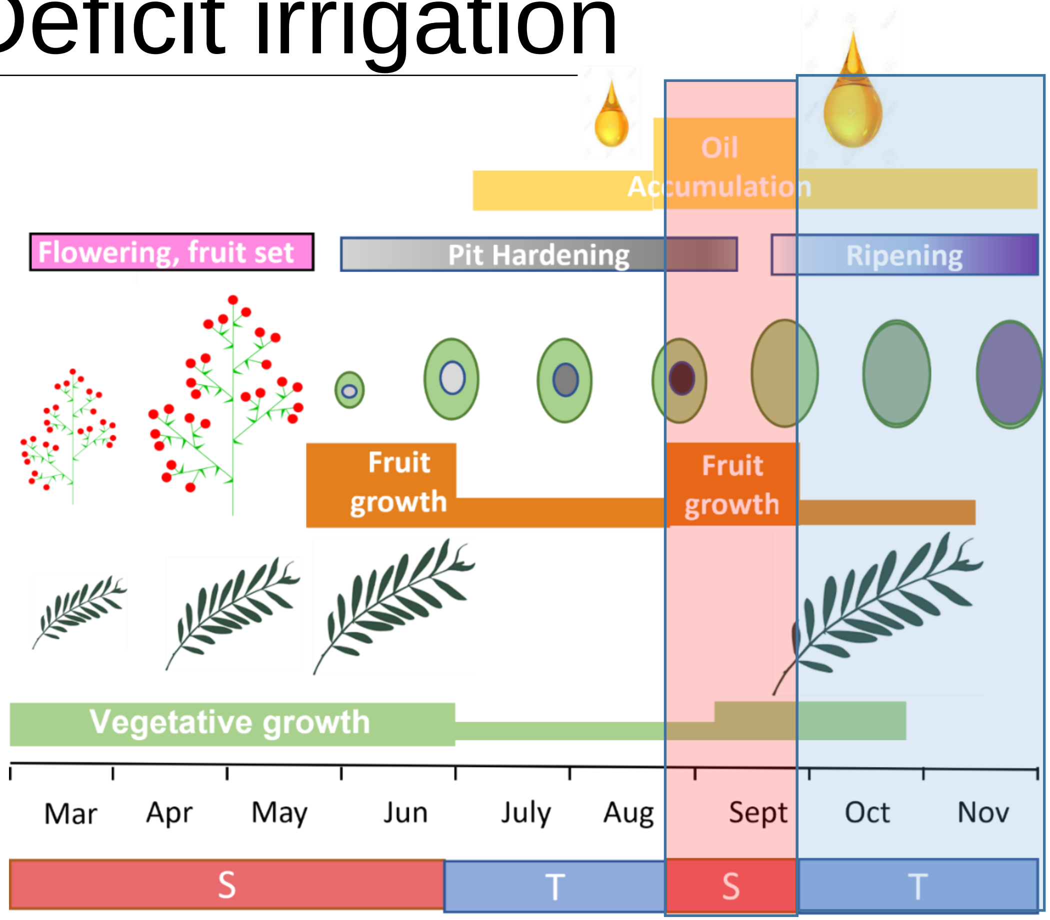
Phenological stage	Response	SWP range
Vegetative growth	Maximum growth	about -10 bars
	Significant growth reduction	-10 to -12 bars
	Strong growth reduction	-20 bars
Flower development	Maximum flowering	about -10 bars
	Significant reduction in flowers	-20 bars
Fruit set/endocarp growth	Maximum fruit set	about -10 bars
	Little or no effect on endocarp growth	-20 bars
	Reduction in fruit size at harvest	-30 bars

Regulated Deficit irrigation



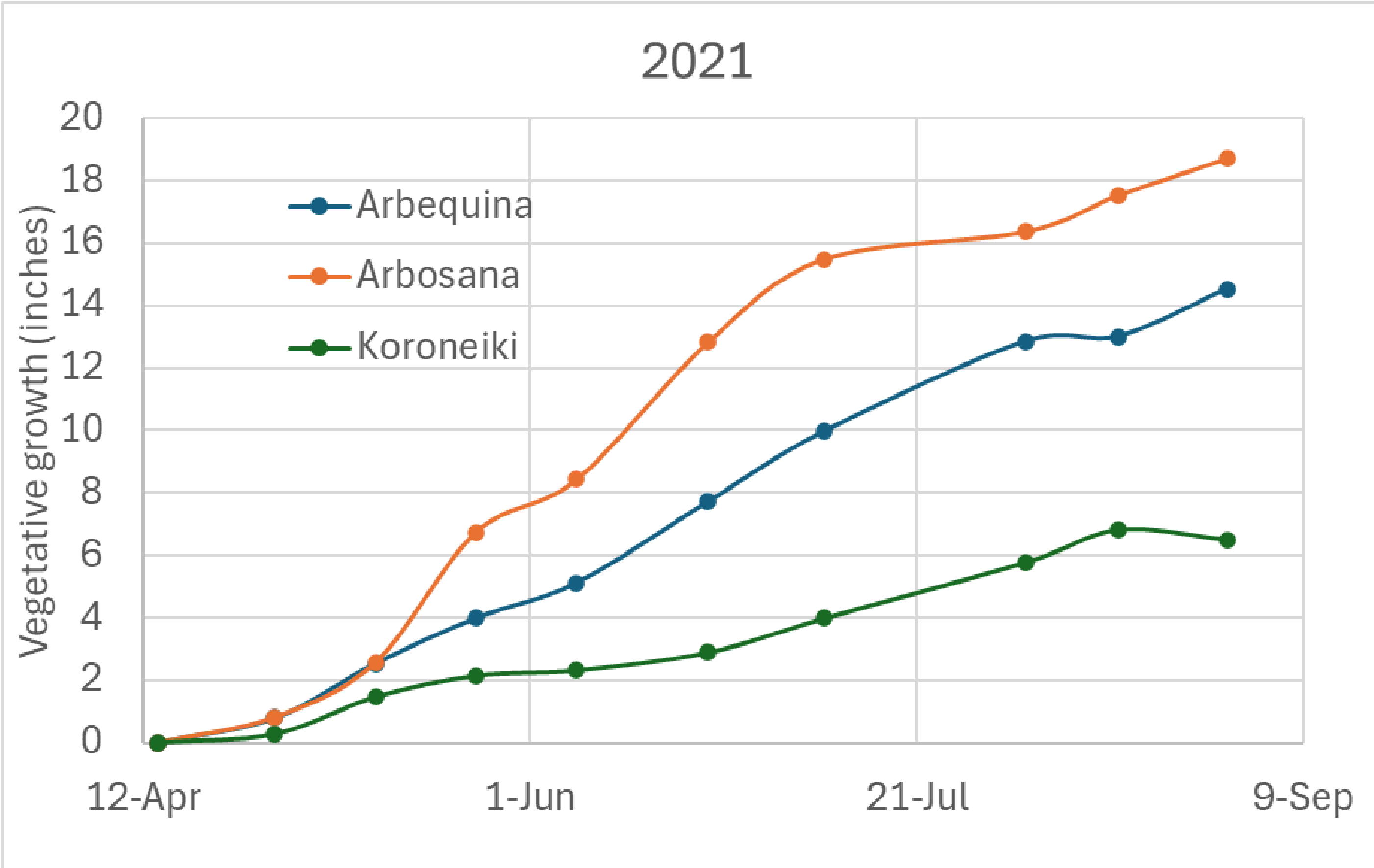
Phenological stage	Response	SWP range
Pit hardening	No significant yield reduction with rehydration next phase. Negligible fruit drop	-20 to -30 bars
	Significant yield reduction. Fruit drop.	-30 to -40 bars
	Fruit shrinkage. Permanent injury to table olives	Below -40 bars

Regulated Deficit irrigation



Phenological stage	Response	SWP range
Fruit growth due to cell expansion (Table and oil olives)	No significant yield reduction. No significantly lower fruit size	> about -15 bars
Oil quantity and quality (oil olives)	No significant effect on oil accumulation	> -20 bars
	Increase in phenolic compounds	Linear increase from -20 to -30 bars
	Increase in oil extractability	-30 bars
	Decrease phenolic compounds	Below -30 bars

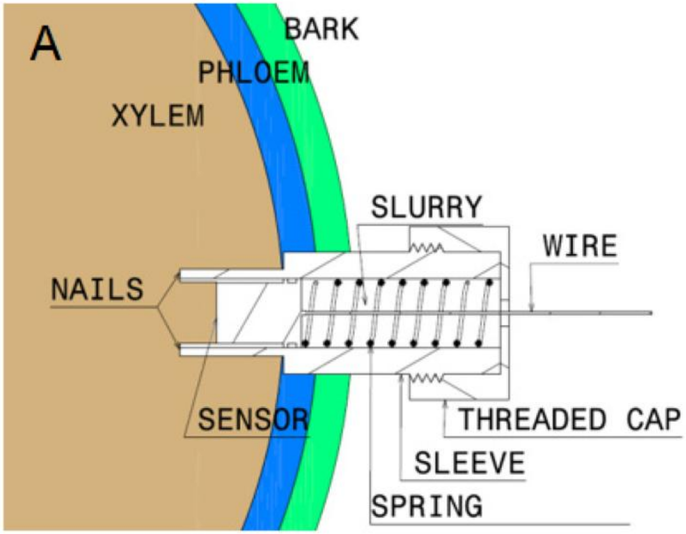
When there is no crop vegetative growth may continue though the entire season



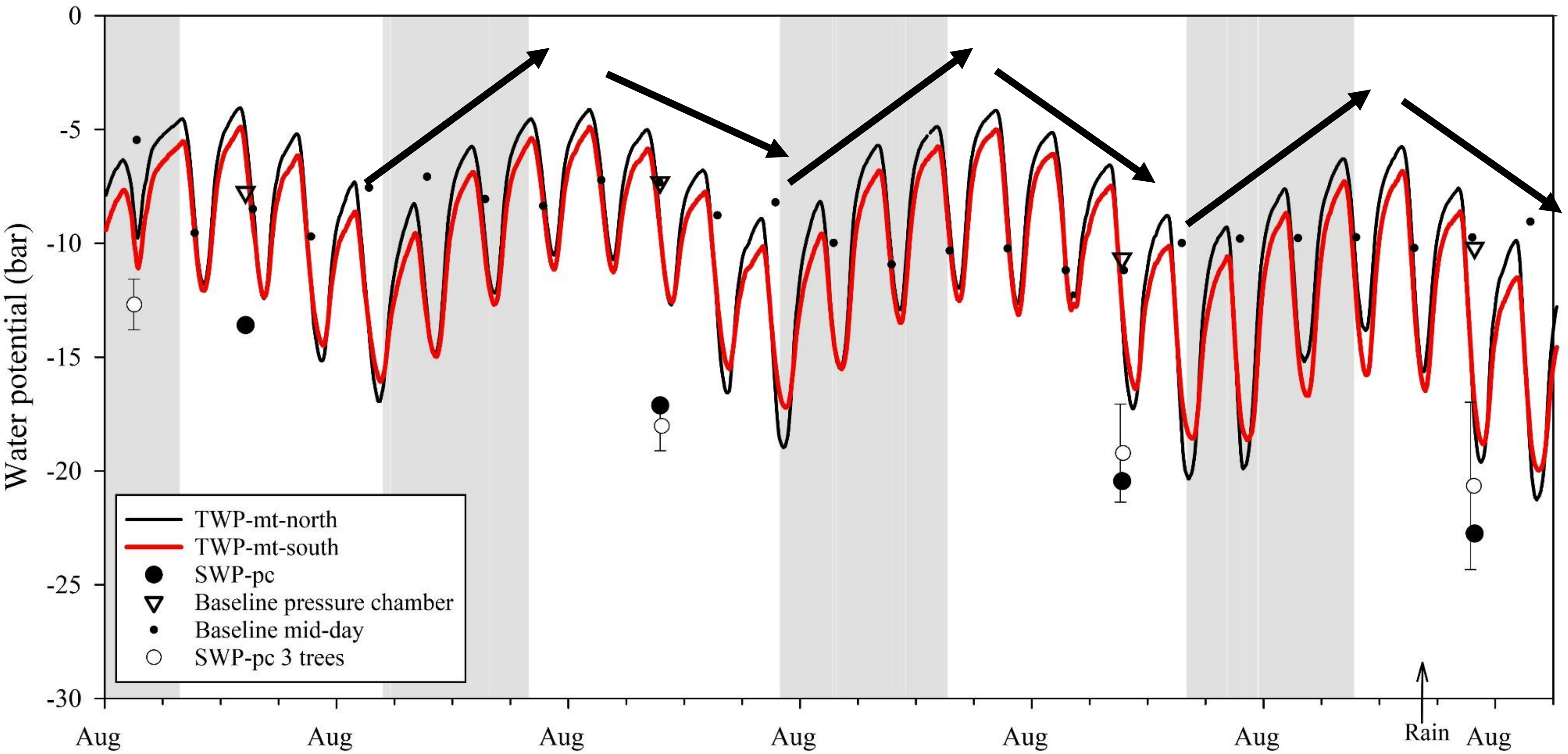
Orchard planted in 2020, at 622 trees per acre


Microtensiometer

Methods


A
BARK
PHLOEM
XYLEM
SLURRY
WIRE
NAILS
SENSOR
THREADED CAP
SLEEVE
SPRING

Continuous water potential measurement

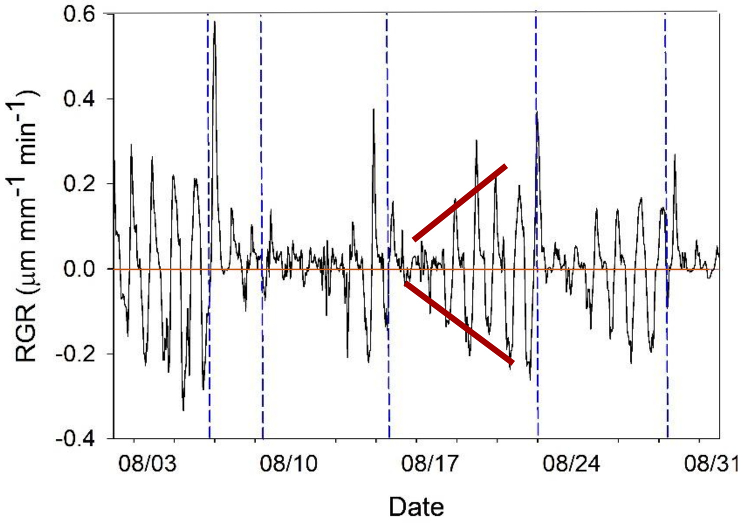


3) Physiologically-based Deficit Irrigation

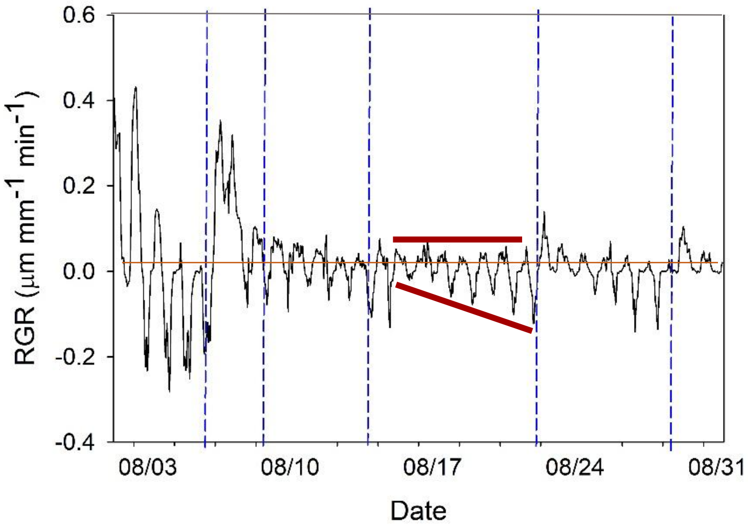
Objective b) Automatic detection of the thresholds

Indicator: **RGR_{range} increase**

Drought resistant genotype



Drought susceptible genotype



Need of genotype-sensitive approach for the continuous monitoring of tree water status by plant based sensing

Marino et al. *2022.*

Fertilization

- Fist year: 4-8 doses of 4-8 grams of urea per plant, or 10g ammonium nitrate, alternating with 10g of potassium (or 10 calcium nitrate) per plant per week (or 15 days)
- Foliar Zinc, Mn, Fe(alkalines soil) and nitrogen based on leaf analysis (1 kg zinc sulfate, 1 kg mn sulfate, 5 kg urea in 1000 liter of water)

Recommended dosages for intensive orchard

Nitrogen; 150 kg/ ha./ year

Phosphorous; 35 kg / ha./ year

Potassium; 200 kg / ha./ year

Critical leaf levels

Nutrient		Deficiency	Sufficiency	Over-fertilization toxicity
N	%	< 1.4	1.5-2.0 > 1.2-1.3 ***1.4-1.8***	***> 1.9***
P	%	0.05	0.1-0.3 ***< 0.13***	
K	%	0.4	> 0.8 ***> 0.9***	
Ca	%	0.30	> 1.0	
Mg	%	0.08	> 0.1	
Na				> 0.2
Fe	mg kg^{-1}		none	
Mn	mg kg^{-1}		> 20	
Zn	mg kg^{-1}		> 10 ***> 8***	
B	mg kg^{-1}	14	19–150	185
Cu	mg kg^{-1}		> 4	
Cl	%			> 0.5

July sampling

Dag et al., 2023. Nutrition and Fertilization. In: The Olive Botany and Production. pp 374-414.

Take-home Messages

- Although olive can survive with very little water, precise irrigation is essential to optimizes vegetative growth in young orchards

- Seasonal water usage (crop evapotranspiration, ETc) from April to November of a mature olive orchard is about 25 inches, one of the lowest water usage levels of all California crops.

- A reduction coefficient needs to be applied for young orchard based on ground canopy shade measurements

- Irrigating to match crop evapotranspiration may lead to over and underestimation of young olive tree

- information on soil or tree water status should be integrated for a more precise assessment of irrigation needs.

- Stem water potential readings with a pressure chamber are the gold standard for determining when to irrigate, but measurements are labor intensive and limited to recording a single point in time.

- Continuous monitoring of plant water status can facilitate irrigation management. However, interpretation of the information can be complex.

THANK YOU!

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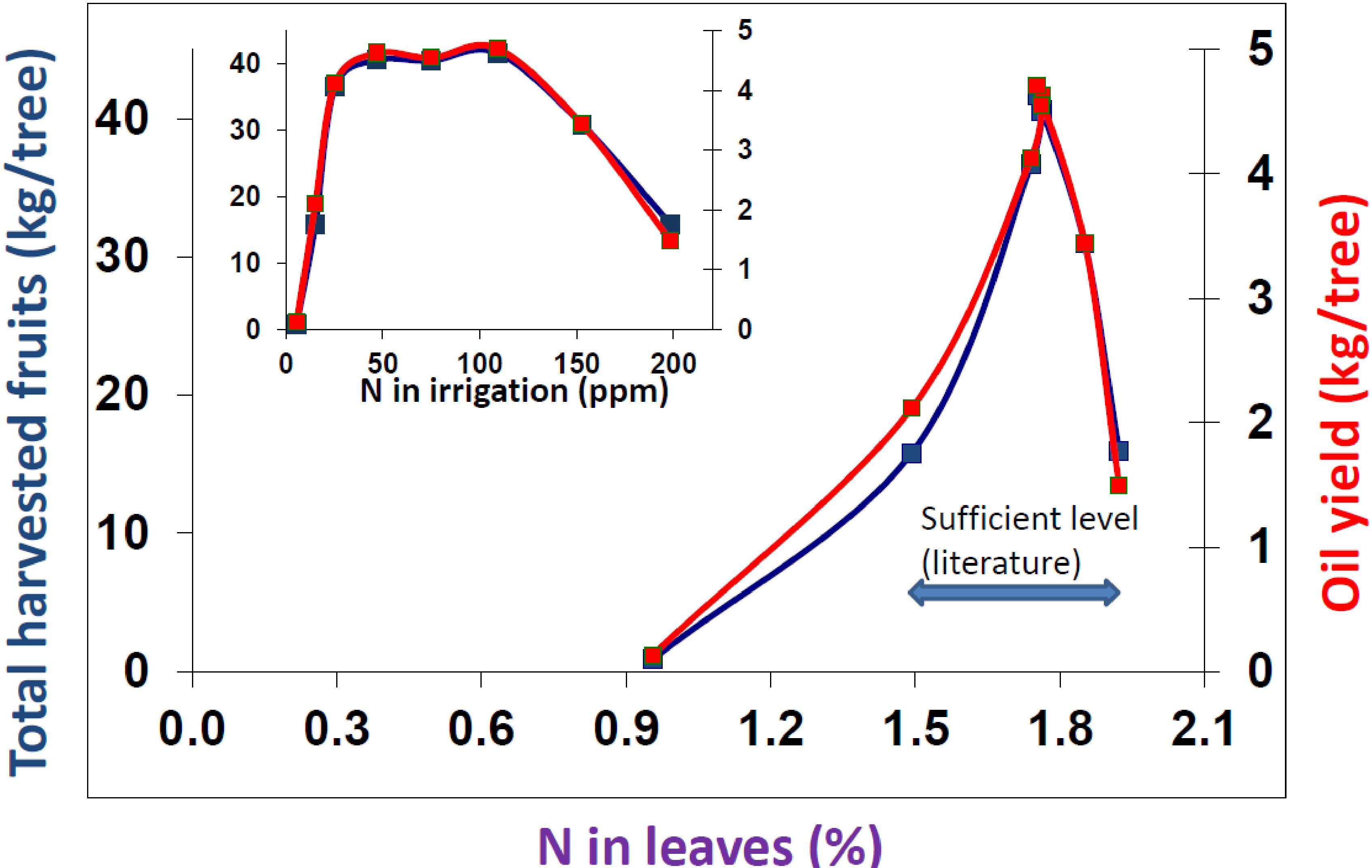
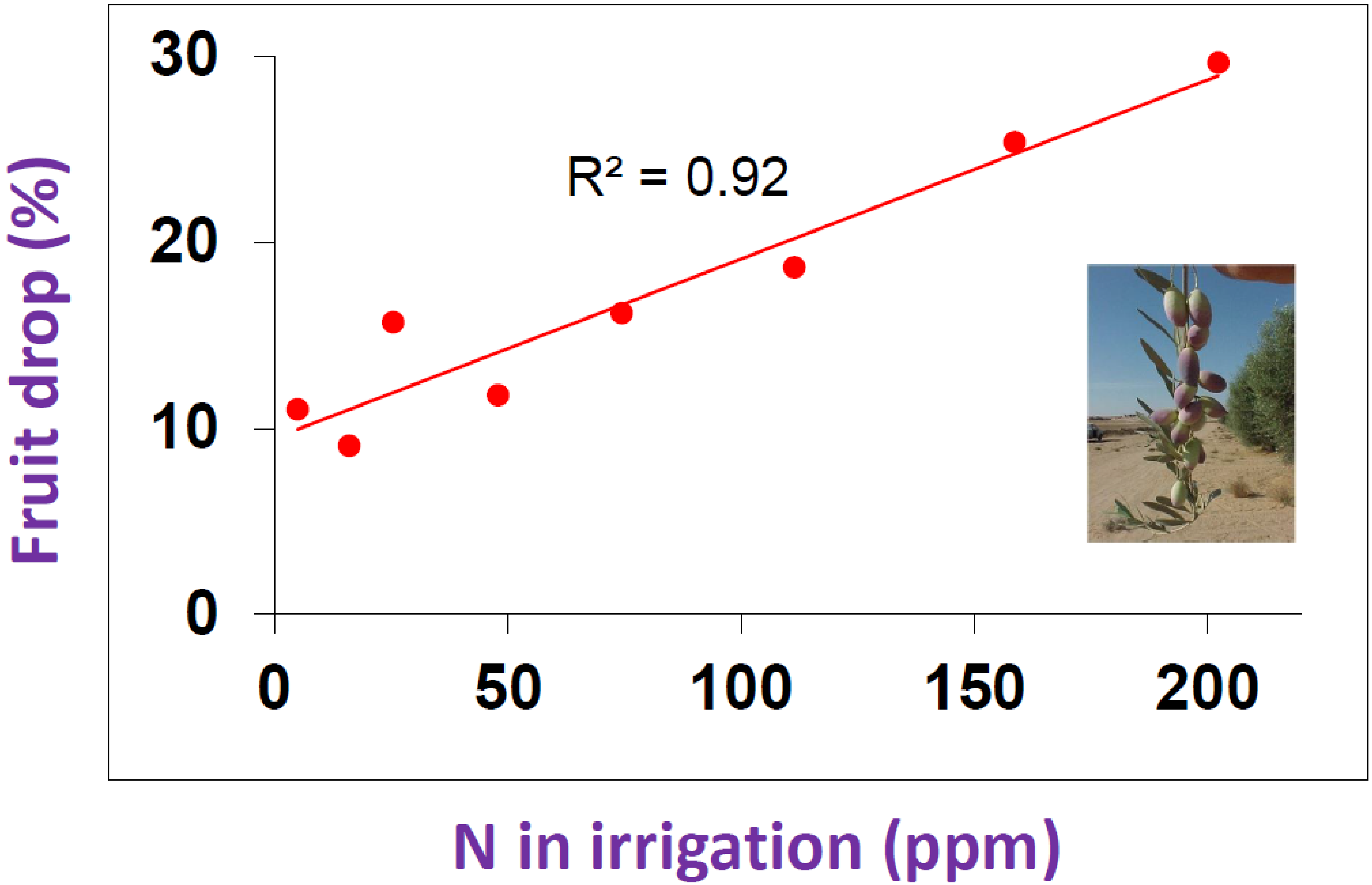
Funding for developing some of the data reported was made possible by the U.S. Department of Agriculture’s (USDA) Agricultural Marketing Service through grant AM22SCBPCA1133. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

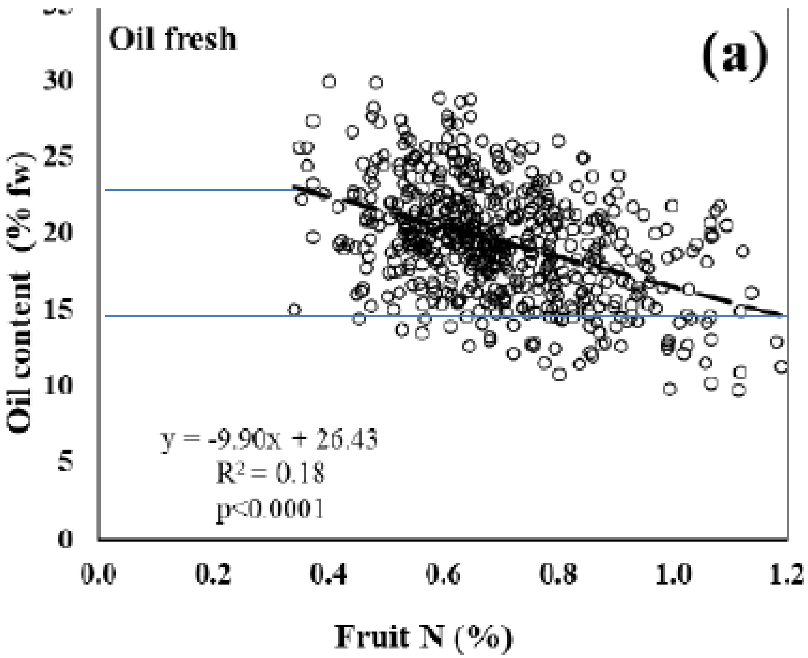
The effect of nitrogen level in leaves on fruit and oil yield

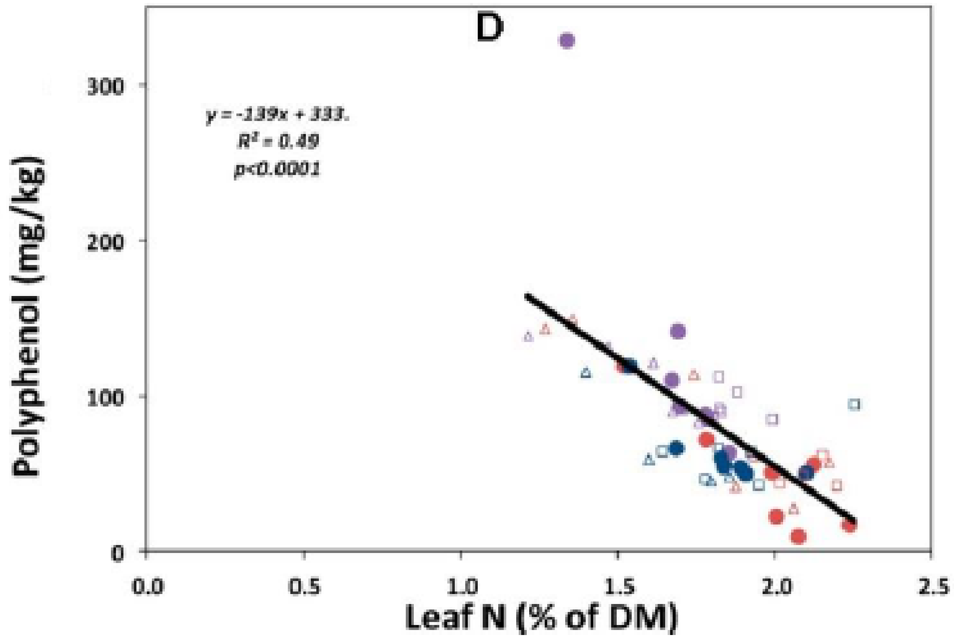


Erel et al., (2013) Scientia Hort.

The correlation between nitrogen level in Irrigation solution and fruit drop




Oil fresh
(a)
Oil content (% fw)
Fruit N (%)
y = -9.90x + 26.43
R² = 0.18
p<0.0001
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30


D
Polyphenol (mg/kg)
Leaf N (% of DM)
y = -139x + 333.
R² = 0.49
p<0.0001
0
100
200
300
0.0
0.5
1.0
1.5
2.0
2.5

The correlation between phosphorous level in diagnostic leaves and fruit and oil yield