The Role of Water in Walnut Tree Growth and Development

Bruce Lampinen
Rick Buchner
Allan Fulton
Joe Grant
Terry Prichard
Cayle Little
Larry Schwankl
Cyndi Gilles
Sam Metcalf
Dan Rivers
Valerie Gamble
Ken Shackel

Question:

Two guys come in from being outside. One says it's cold, the other says it's not.

What can you ask to decide for yourself?

The plant on the right is obviously water stressed, but what can we measure to be more sure?

Salisbury & Ross, Plant Physiology (1992)

Soil moisture?

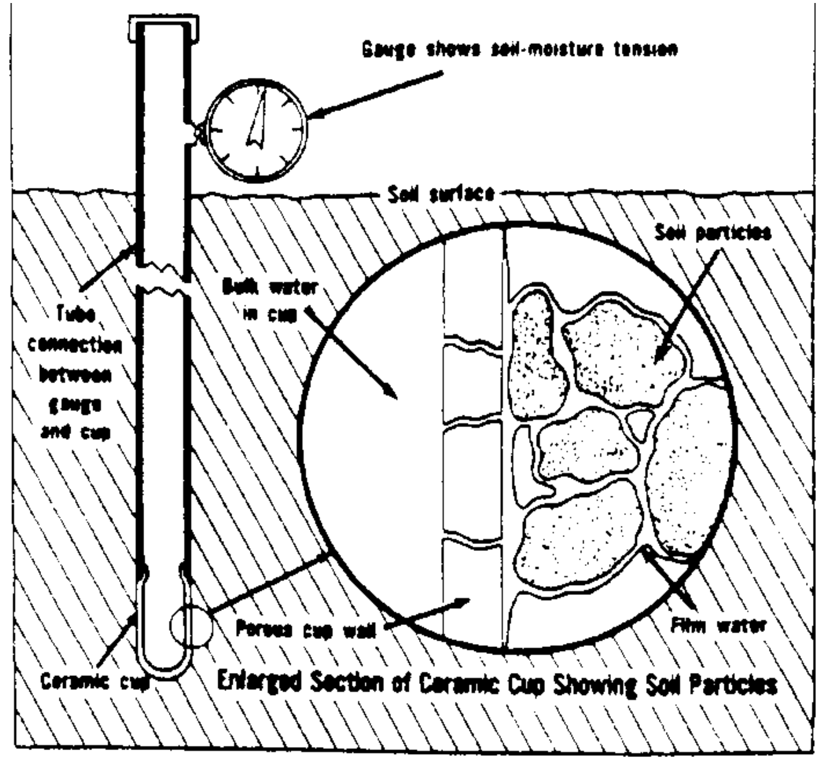
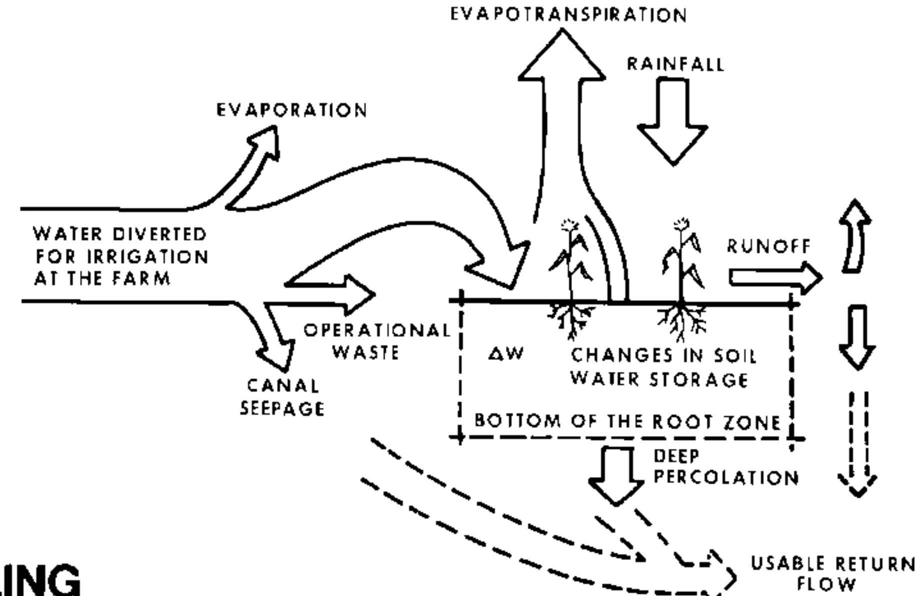


Fig. 8–1. Cross-section of a tensiometer. Essential parts include porous cup, connecting tube, vacuum gauge, and removable stopper or cap. The enlarged section schematic diagram shows how water films surrounding soil particles connect with bulk water in the tensiometer. (From Richards and Hagan, 1958.)

Key problem with trees: how deep and where?

Applied water?



ig 1 Water balance of a field.

3

BASIC IRRIGATION SCHEDULING

Farmers use numerous ways to schedule irrigations. This leaflet describes two technical procedures. The water budget procedure, which is based on supplying water needs or requirements of the crop, is the most complete. Use of devices which sense water in the soil is also described briefly.

WATER REQUIREMENTS

Water is lost from a cropped field in two ways: direct evaporation of water from the soil surface, and transpiration, which is loss of water vapor from plant leaves. This combination of evaporation from the soil and transpiration by the plant is called evapotranspiration (ET). It is the "crop water requirement"—the amount of water actually used by the growing crop.

However, delivering water to the farm and applying it to the land involves losses by runoff or percolation below the root zone. These losses can be minimized through good conservation practices, but they are difficult to eliminate and must be included to determine the "irrigation water requirement". In general:

Irrigation Requirement – ET – Effective Rainfall – Irrigation System Losses

In the northern and central parts of California, rainfall supplies an appreciable portion of the crop needs in normal years. Some rain may fall after the crop is planted, but most is stored in the soil from pre-season rains. Growers need to estimate the amount of rainfall stored at the beginning of the season, as it is too important to be ignored.

Figure 1 shows water received and potential losses at the farm level during and after irrigation. If losses are kept to a minimum, most of the applied water goes to meet the ET demand.

Typically stated objective of irrigation:
"Apply water to match ET"

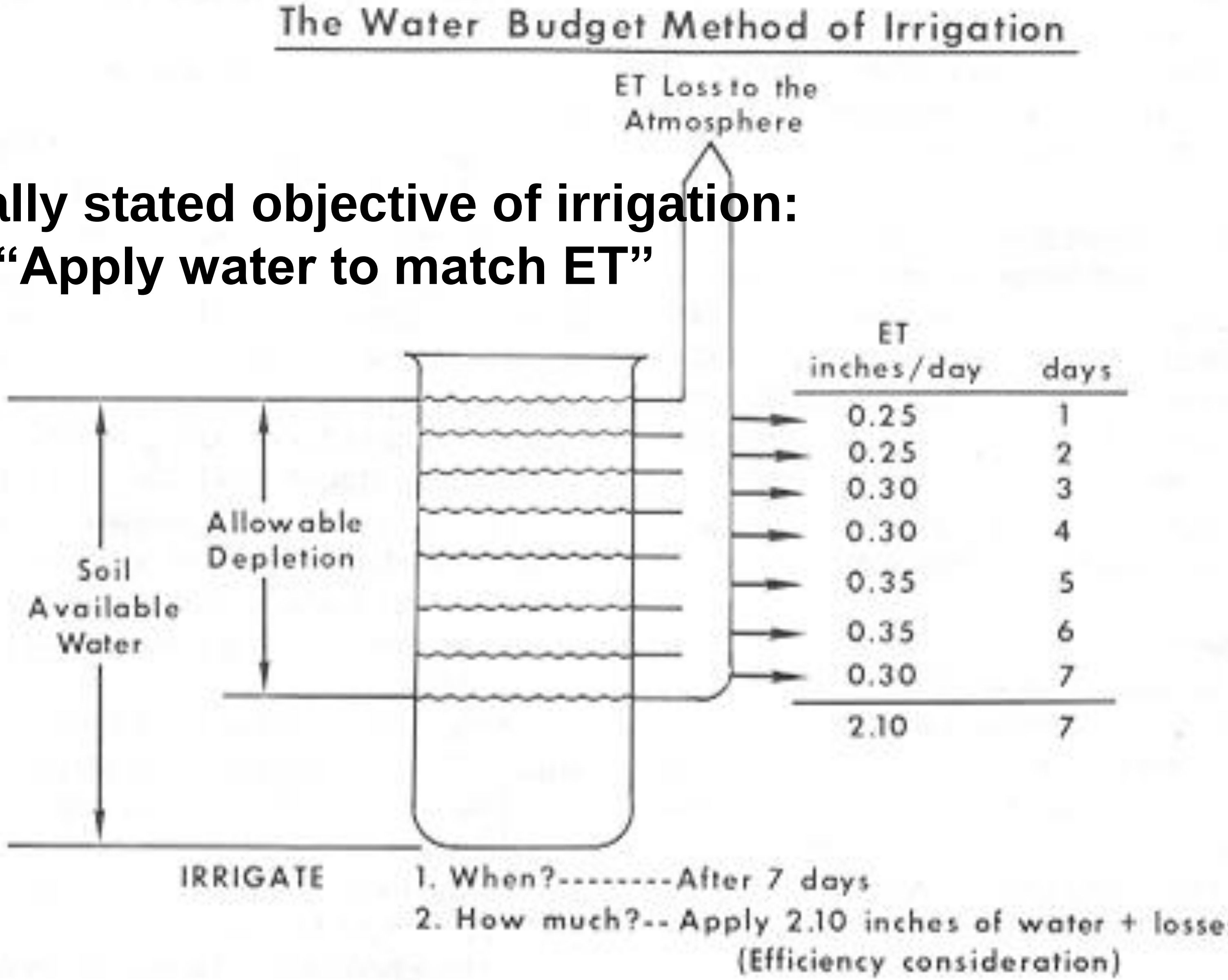


Fig. 2. Water-budget method of irrigation.

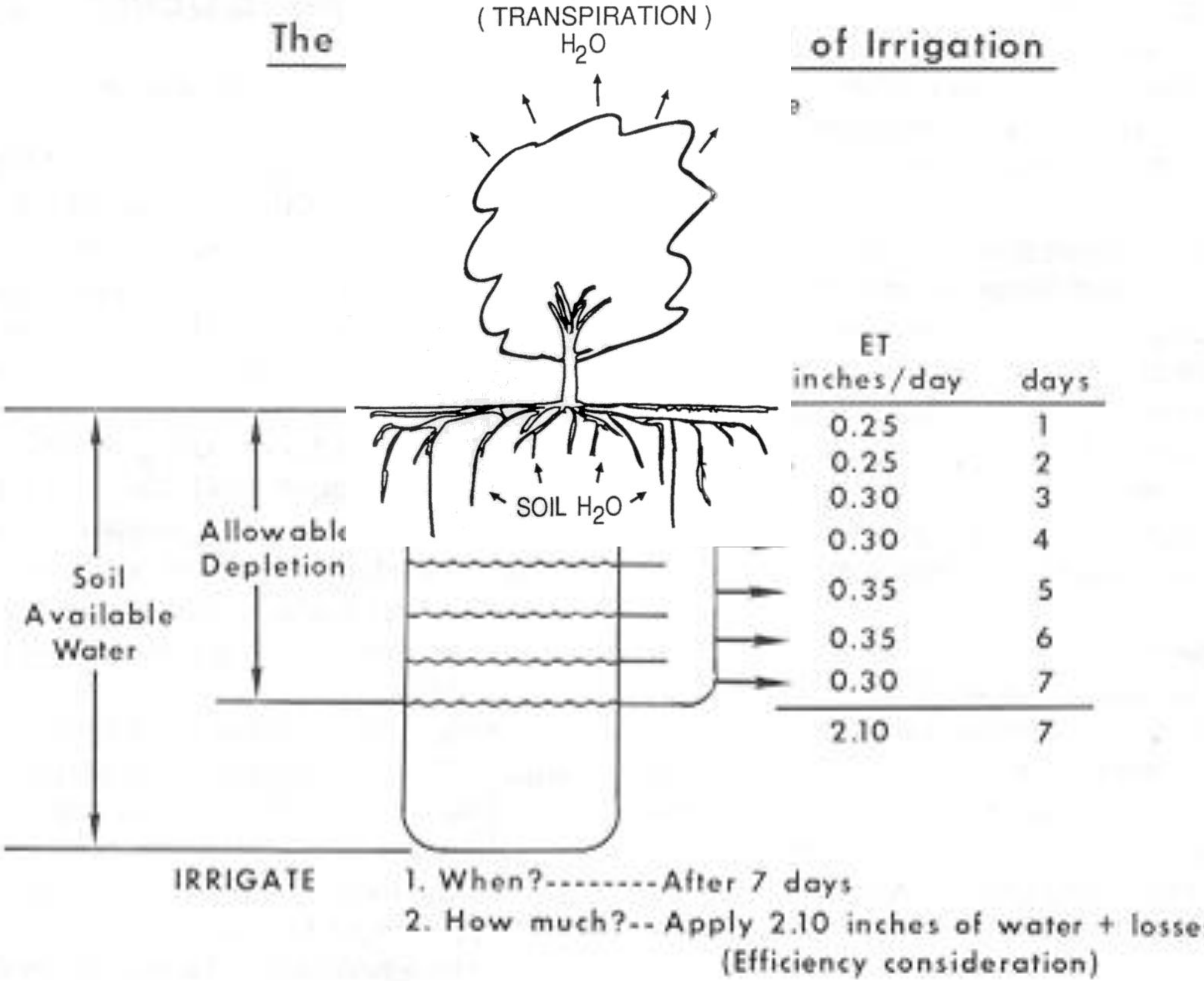
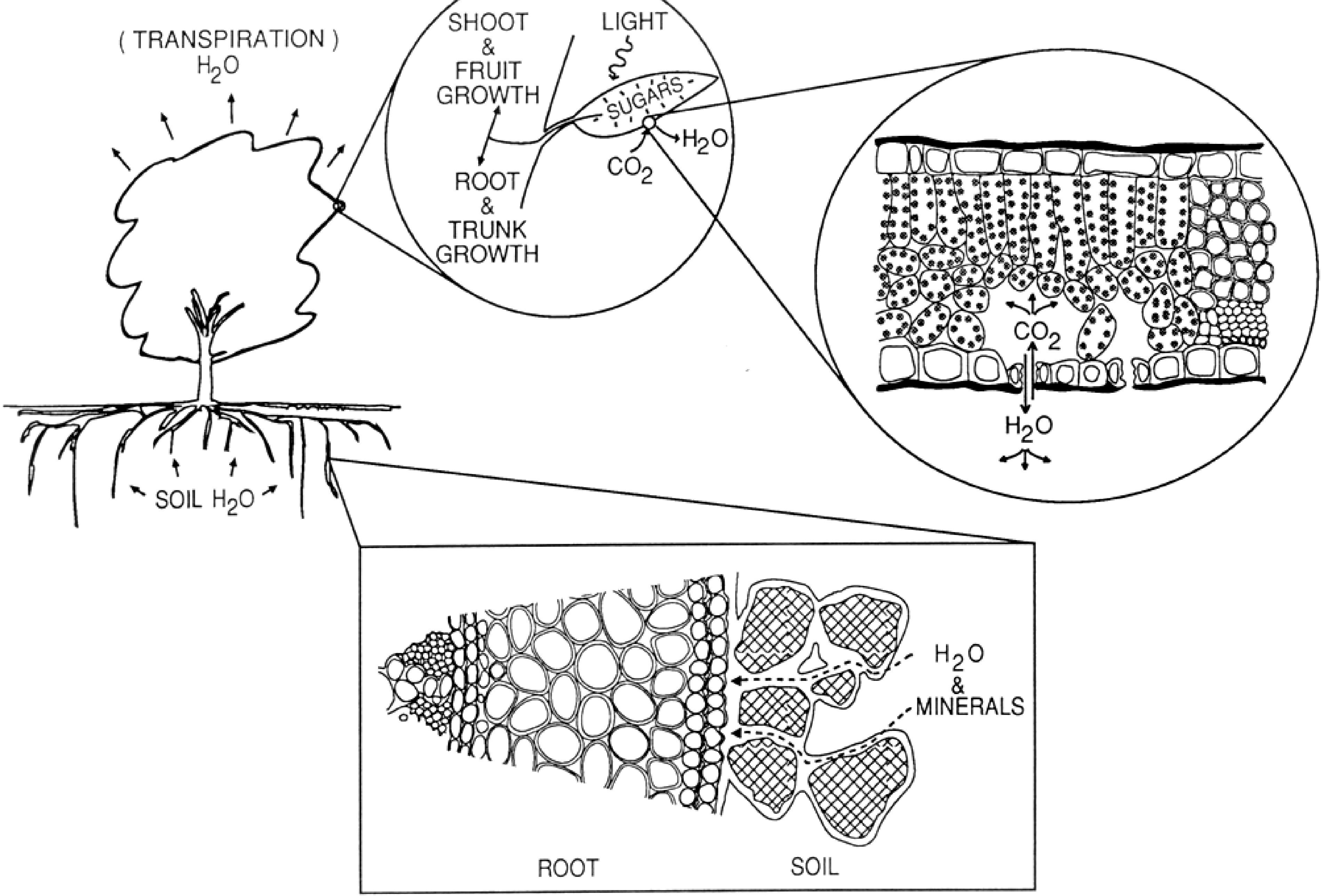


Fig. 2. Water-budget method of irrigation.

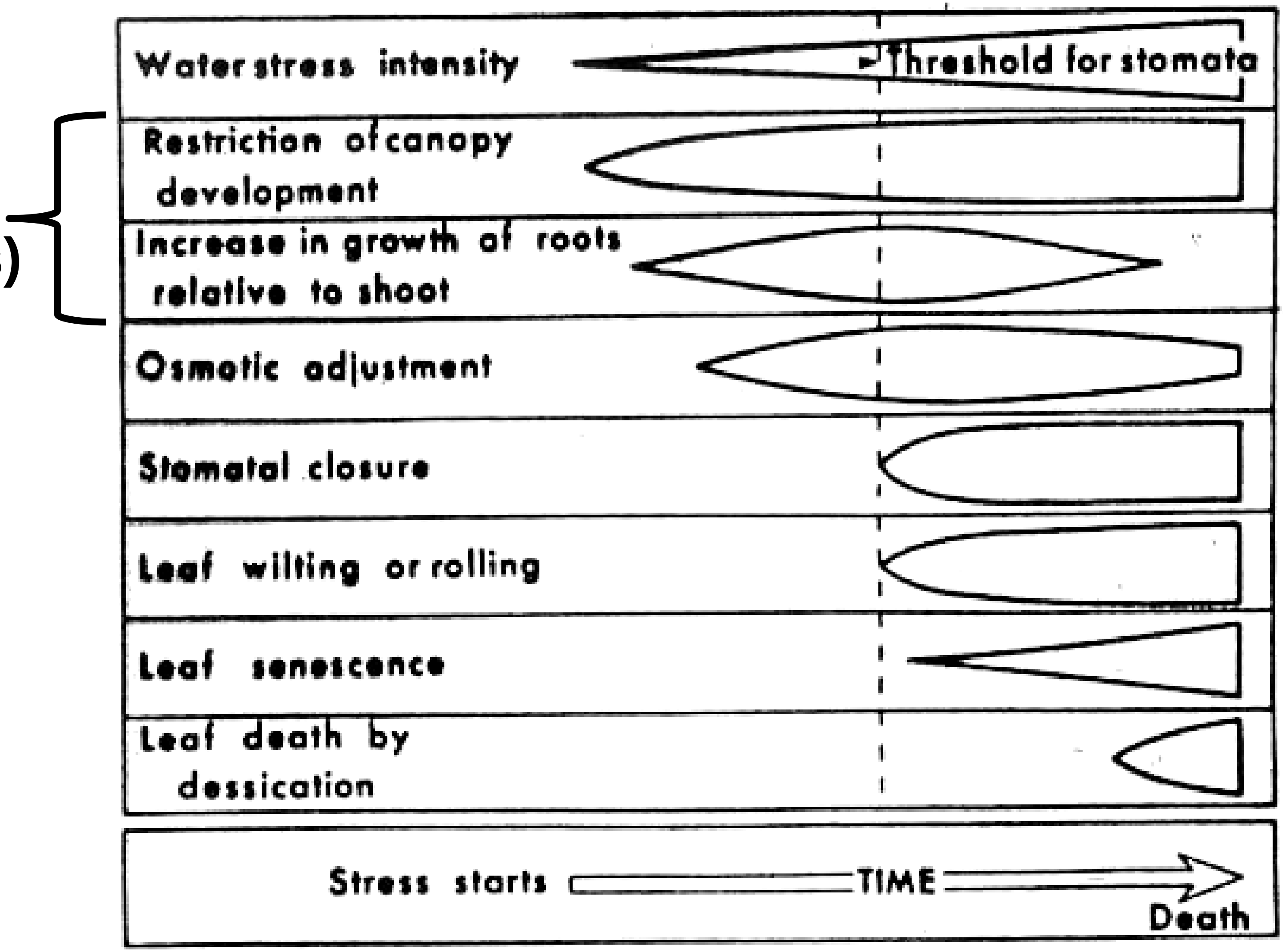

(TRANSPIRATION)
H_2O
SHOOT & FRUIT GROWTH
ROOT & TRUNK GROWTH
LIGHT
SUGARS
H_2O
CO_2
CO_2
H_2O
SOIL H_2O
H_2O & MINERALS
ROOT
SOIL

Wilting = water sucked out of cells

Salisbury & Ross, Plant Physiology (1992)

Early symptoms of stress: reduction in <u>growth</u>

(growth processes)



Bradford and Hsiao, 1982, Encyclopedia of Plant Physiology. 12B:263-324.

Typically stated objective of irrigation:
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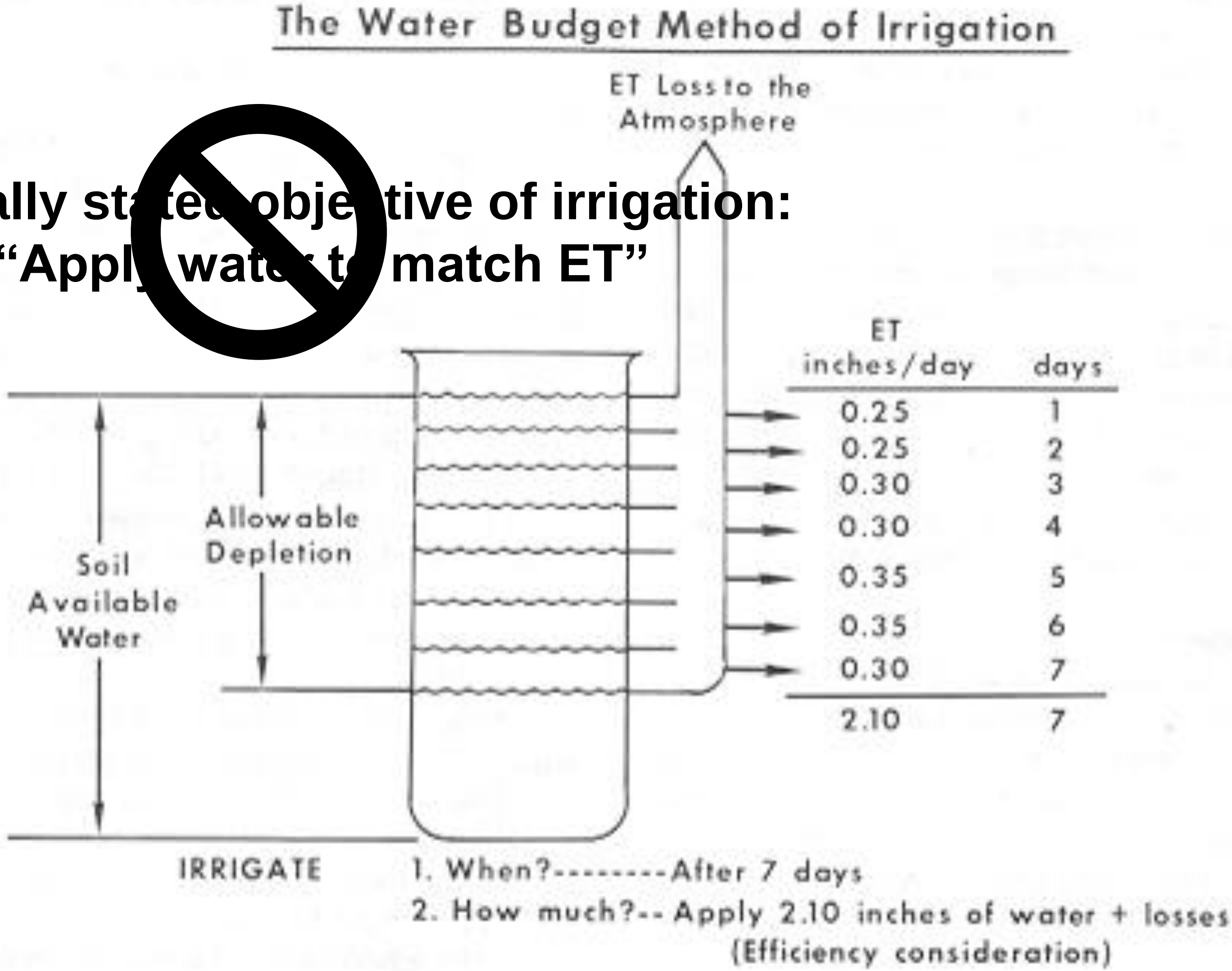
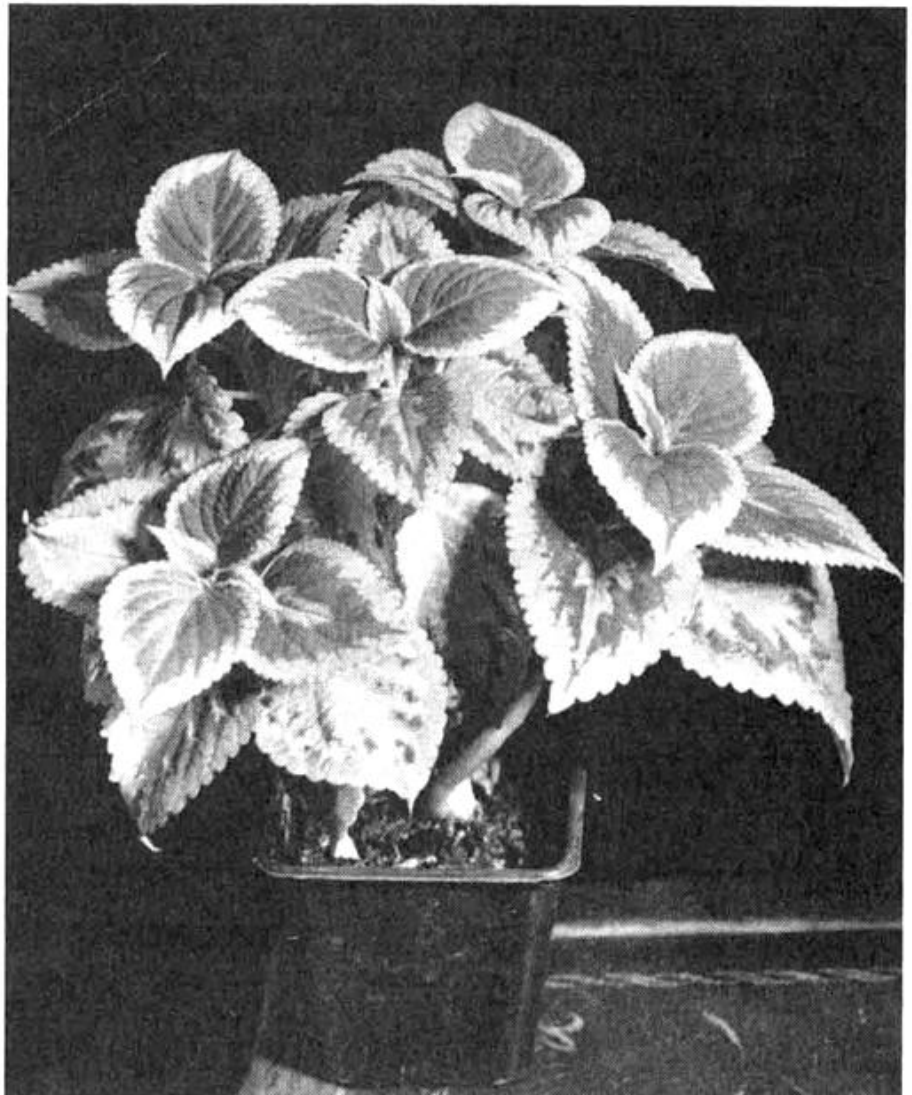
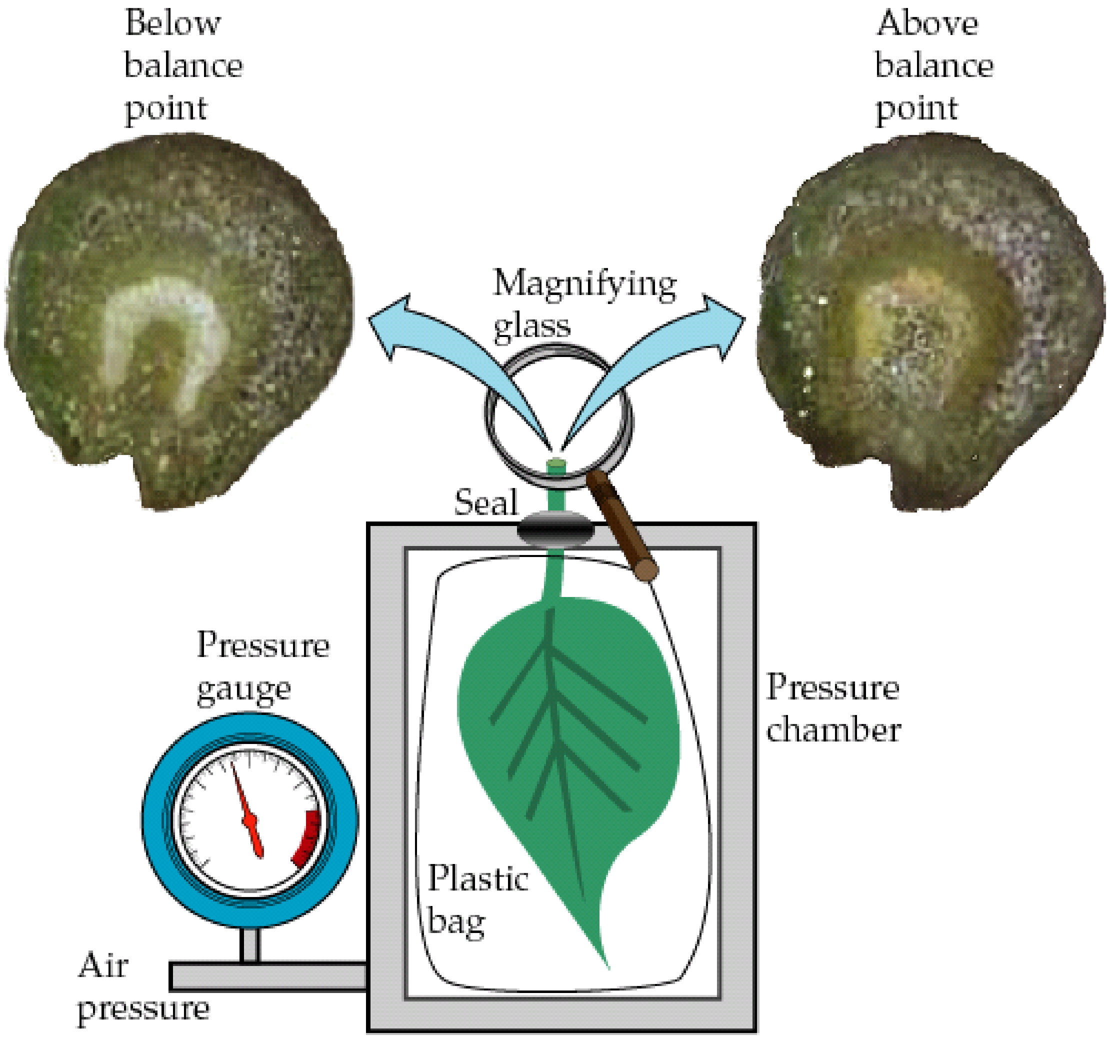


Fig. 2. Water-budget method of irrigation.

More appropriate objective of irrigation in agriculture:
"Manipulate plant water status to achieve some production objective"



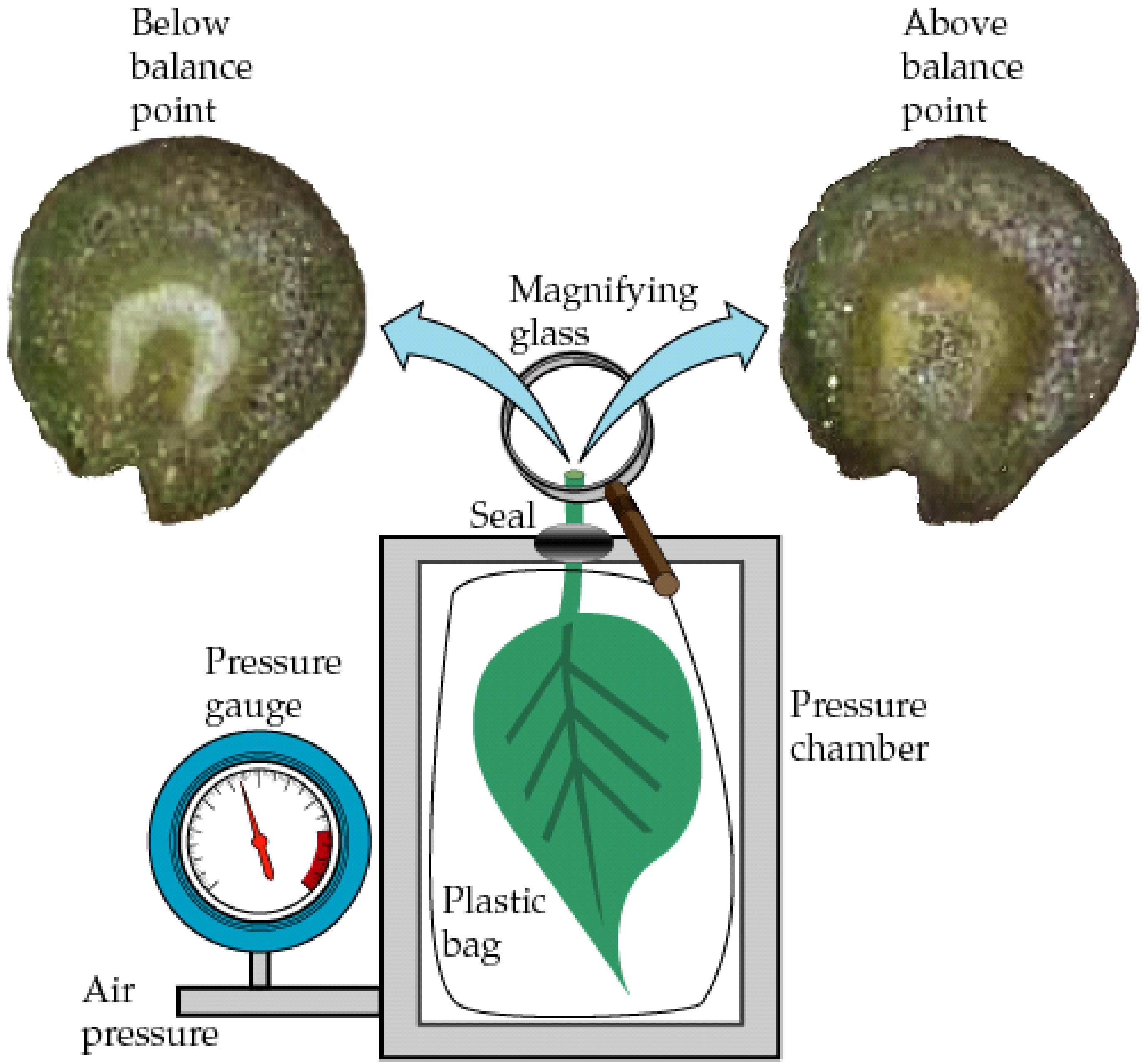
Salisbury & Ross, Plant Physiology (1992)



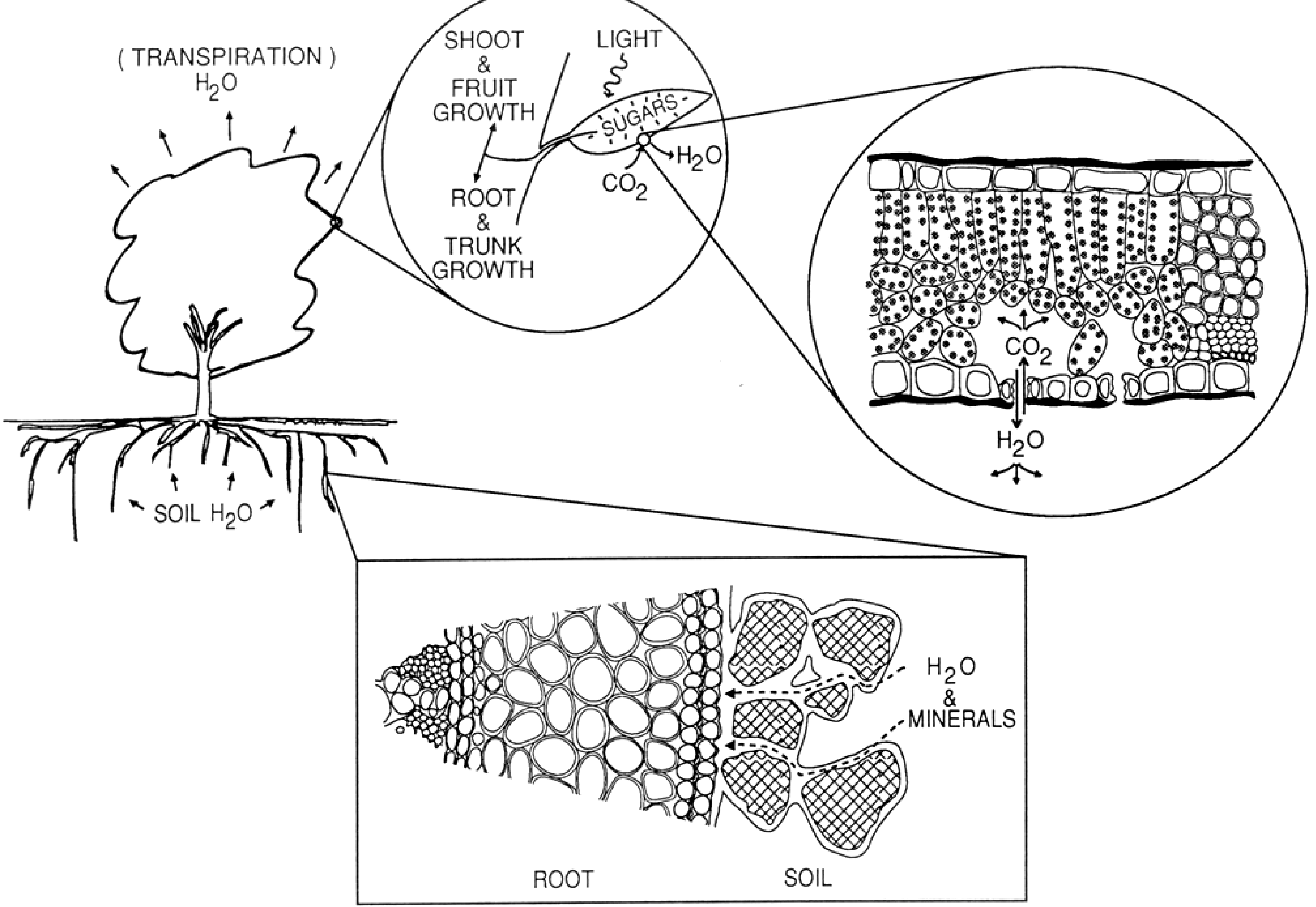
Like measuring the “blood pressure” of the plant


Stem Water Potential
(SWP)

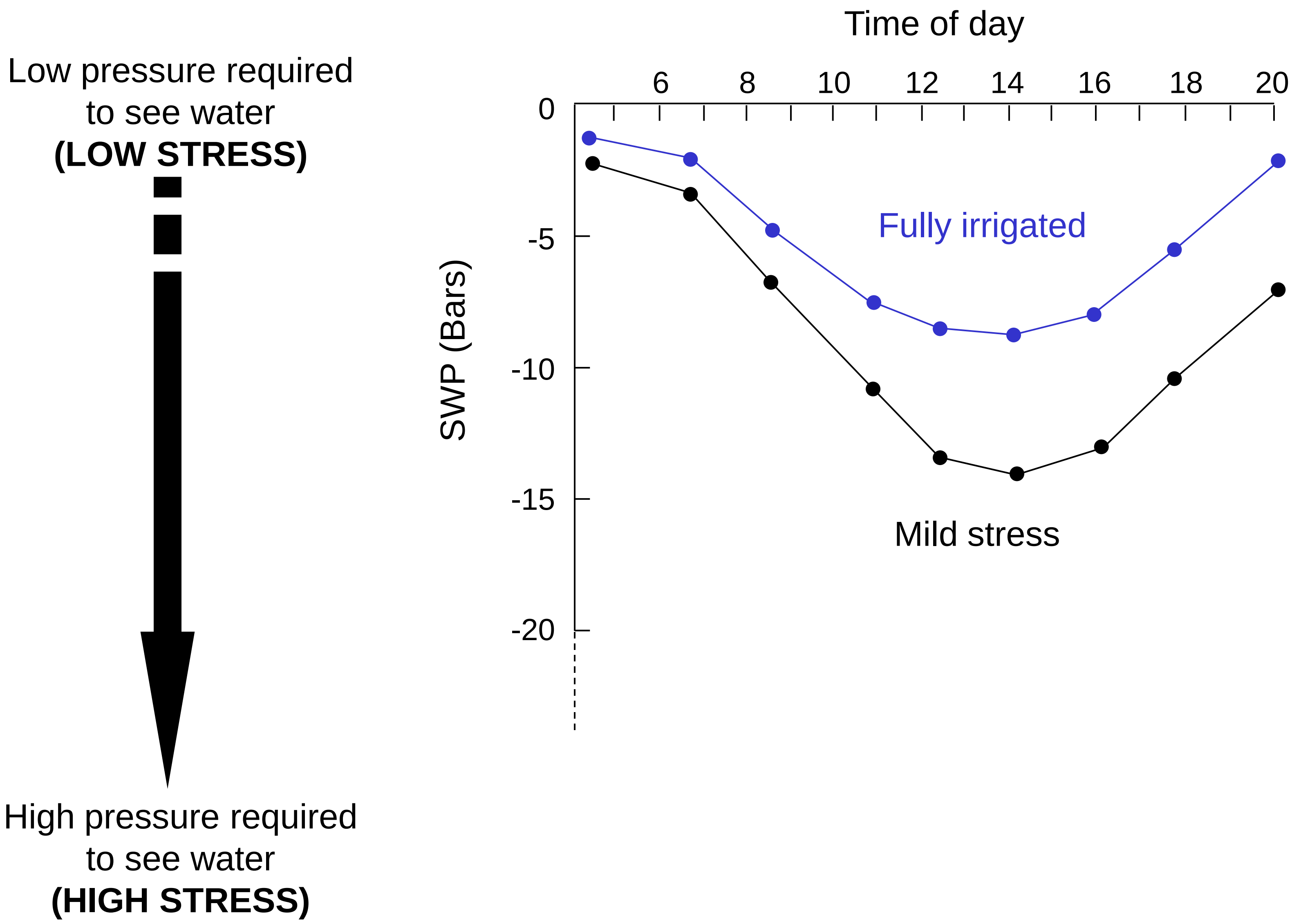

What you see under
the magnifying glass
Leaf stem (petiole)
Xylem (“veins”)


Below balance point
Above balance point
Magnifying glass
Seal
Pressure gauge
Pressure chamber
Plastic bag
Air pressure


S10
CHEVROLET
CORNING
California
E 034608


(TRANSPIRATION)
H_2O
SHOOT & FRUIT GROWTH
LIGHT
SUGARS
H_2O
CO_2
ROOT & TRUNK GROWTH
CO_2
H_2O
SOIL H_2O
H_2O & MINERALS
ROOT
SOIL

Typical example of the daily pattern in SWP



“Baseline” values of midday SWP (Bar) under various air temperature and RH conditions for Walnut

Air Temperature (F)	Air RH (%)		
	20	40	60
60	-3.7	-3.5	-3.2
70	-4.1	-3.7	-3.4
80	-4.6	-4.1	-3.7
90	-5.2	-4.6	-4.0
100	-6.1	-5.3	-4.5
110	-7.3	-6.2	-5.0

TENTATIVE GUIDELINES FOR INTERPRETING PRESSURE CHAMBER READINGS (MIDDAY STEM WATER POTENTIAL-SWP) IN WALNUT, ALMOND, AND DRIED PLUM. UPDATED MAY 2007.

Allan Fulton and Richard Buchner, UCCE Farm Advisors, Tehama County, Joe Grant, Farm Advisor, San Joaquin County, Terry Prichard, Bruce Lampinen, Larry Schwankl, Extension Specialists, UC Davis, and Ken Shackel, Professor UC Davis.

Pressure Chamber Reading (- bars)	WALNUT	ALMOND	PRUNES
0 to –2.0	Not commonly observed	Not commonly observed	Not commonly observed
-2.0 to –4.0	Fully irrigated, low stress, commonly observed when orchards are irrigated according to estimates of real-time evapotranspiration (ETc), long term root and tree health may be a concern, especially on California Black rootstock.	↓	↓
-4.0 to –6.0	Low to mild stress, high rate of shoot growth visible, suggested level from leaf-out until mid June when nut sizing is completed.	↓	↓
-6.0 to –8.0	Mild to moderate stress, shoot growth in non-bearing and bearing trees has been observed to decline. These levels do not appear to affect kernel development.	Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth. Suggest maintaining these levels from leaf-out through mid June.	Low stress, common from March to mid April under fully irrigated conditions. Ideal for maximum shoot growth.
-8.0 to –10.0	Moderate to high stress, shoot growth in non-bearing trees may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.	↓	Suggested levels in late April through mid June. Low stress levels enabling shoot growth and fruit sizing.
-10.0 to –12.0	High stress, temporary wilting of leaves has been observed. New shoot growth may be sparse or absent and some defoliation may be evident. Nut size likely to be reduced.	Mild to moderate stress, these levels of stress may be appropriate during the phase of growth just before the onset of hull split (late June).	Suggested mild levels of stress during late June and July. Shoot growth slowed but fruit sizing unaffected.
-12.0 to –14.0	Relative high levels of stress, moderate to severe defoliation, should be avoided.	↓	Mild to moderate stress suggested for August to achieve desirable sugar content in fruit and to reduce “dry-away” (drying costs).
-14.0 to –18.0	Severe defoliation, trees are likely dying.	Moderate stress in almond. Suggested stress level during hull split, Help control diseases such as hull rot and alternaria, if diseases are present. Hull split occurs more rapidly	Moderate stress acceptable in September.
-18.0 to –20.0	Crop stress levels in English walnut not observed at these levels.	Transitioning from moderate to higher crop stress levels	Moderate to high stress levels. Most commonly observed after harvest. Generally undesirable during any stage of tree or fruit growth. Most appropriately managed with post-harvest irrigation
-20 to -30	↓	High stress, wilting observed, some defoliation	
Less than – 30		Extensive defoliation has been observed	High stress, extensive defoliation

* These guidelines are tentative and subject to change as research and development with the pressure chamber and midday stem water potential progress. This table should not be duplicated without

↓ Around -60

↓ Complete defoliation

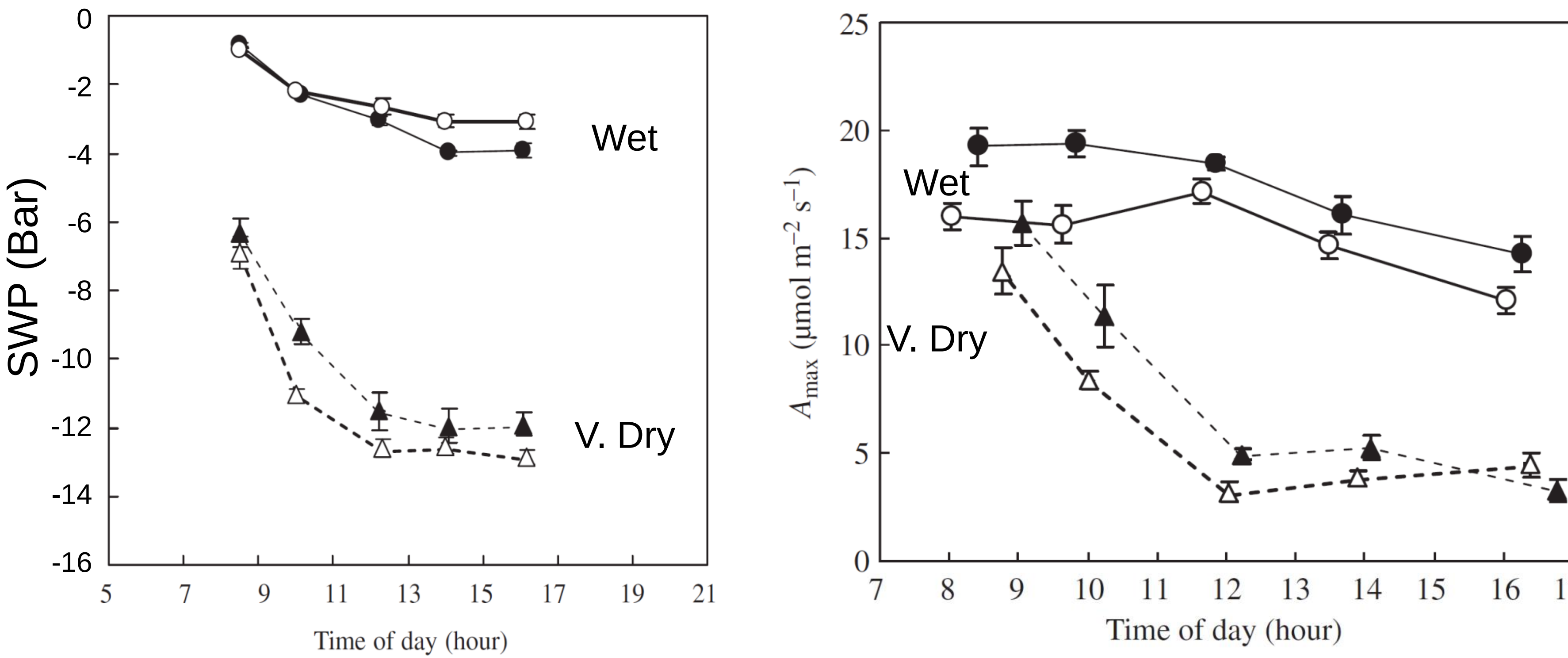
This tree had reached -63 bars on July 14, 2009, and by July 28 was completely defoliated. No flowers or nuts in 2010, but still alive!

	Pressure Chamber Reading (- bars)	WALNUT
	0 to –2.0	Not commonly observed
“Wet”	-2.0 to –4.0	Fully irrigated, low stress, commonly observed when orchards are irrigated according to estimates of real-time evapotranspiration (ETc), long term root and tree health may be a concern, especially on California Black rootstock.
“Medium”	-4.0 to –6.0	Low to mild stress, high rate of shoot growth visible, suggested level from leaf-out until mid June when nut sizing is completed.
	-6.0 to –8.0	Mild to moderate stress, shoot growth in non-bearing and bearing trees has been observed to decline. These levels do not appear to affect kernel development.
“Dry”	-8.0 to –10.0	Moderate to high stress, shoot growth in non-bearing trees may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.

A “Day in the Life:”

Stress and kaolin spray (surround) effects on SWP and photosynthesis in walnut over a day.

(open symbols = sprayed trees)

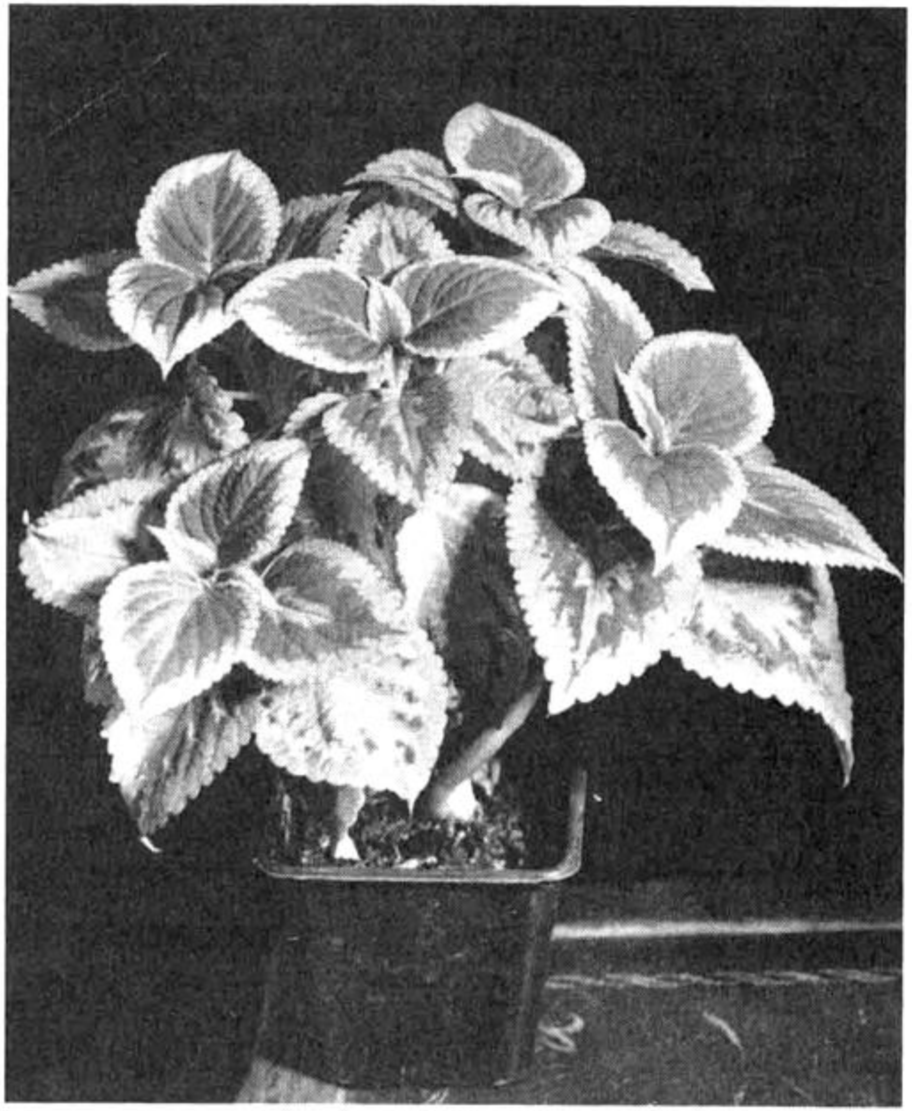


Rosati et al, 2006

RDI: “Regulated Deficit Irrigation”

Concept: Mild to moderate levels of water stress, at the correct time, may *benefit* horticultural crop production or quality, or at least save water without reducing production or quality.

Manipulate plant water status to achieve some production objective



Salisbury & Ross, Plant Physiology (1992)

Benefits of RDI in Prunes:

1) Increase fruit sugar concentration
2) Decrease fruit water content and drying costs
3) Increase flower density and yield
4) Save Water

Proposed benefits of RDI for almonds during hull split:

1) Speed up Hull Split
2) Reduce Hull rot
3) Reduce Sticktights (Improve Harvestability)
4) Save Water

Benefits & risks of deficit irrigation in Walnut

Benefits:

- Reduce water use/pumping costs
- Reduce soil disease pressure
- Reduce **unnecessary** vegetative growth & pruning costs

Risks:

- Reduce **necessary** vegetative growth
- Lower yield and/or quality

Walnut SWP, applied water and yields (dry inshell) for a three year irrigation test with wet, medium and dry irrigation levels

(Sacramento valley Chandler orchard "Black Butte")

Month	2002 Season			2003 Season			2004 Season		
	Wet	Med	Dry	Wet	Med	Dry	Wet	Med	Dry
May	-4.2	-4.5	-5.4	-3.8	-4.2	-4.4	-2.6	-2.7	-2.8
June	-4.0	-4.8	-6.5	-2.5	-4.0	-5.1	-4.8	-5.8	-6.9
July	-3.4	-6.0	-7.8	-2.8	-6.5	-7.5	-5.0	-7.6	-8.9
Aug	-3.3	-6.6	-7.7	-3.2	-7.9	-8.9	-3.2	-6.4	-8.5
Sept	-2.8	-8.9	-9.6	-3.4	-8.5	-10.2	-2.8	-6.0	-8.1
Season Avg	-3.6	-6.2	-7.4	-3.1	-6.2	-7.2	-3.7	-5.7	-7.0
Applied Water (inches)	43.8	31.2	25.8	44.5	26.2	21.7	42.9	26.6	23.3
Yield (T/ac)	**1.98**	**1.84**	**1.76**	**2.72**	**2.22**	**2.01**	**2.17**	**1.59**	**1.28**
% Loss		**-7%**	**-11%**		**-18%**	**-26%**		**-27%**	**-41%**

Fulton et al, 2004


Jun 15, 2005
June, 2005
D
W
M
W
D
M
D
M
W
M
W
D
Problem:
increased tree
loss to disease in
the wet treatment

Similar yield loss in two locations

	Yield (t/ac)			2004 Yield
Black Butte	**2002**	**2003**	**2004**	**Reduction**
Wet	1.98 a	2.82 a	2.24 a	0%
Medium	1.84 a	2.33 b	1.65 b	-26%
Dry	1.74 a	2.07 b	1.31 c	-42%
San Joaquin				
Wet	3.55 a	4.43 a	3.77 a	0%
Medium	3.26 a	3.94 a	2.98 b	-21%
Dry	3.29 a	3.80 a	3.08 b	-18%

The reason for yield loss in 2004: fewer number of nuts/tree

	2004	Nut		Percent reduction	
Black Butte	Yield	Size g.	#Nuts/tree	Yield	# nuts
Wet	2.24 a	10.71 a	2,342	0%	0%
Medium	1.65 b	11.14 a	1,659	-26%	-29%
Dry	1.31 c	10.94 a	1,341	-42%	-43%
San Joaquin					
Wet	3.77 a	11.92 a	5,856	0%	0%
Medium	3.03 b	11.87 a	4,726	-20%	-19%

No treatment effects on % retention in 2004 (i.e., losses occur prior to bloom)

	% Retention	% Retention	2004 Yield
Black Butte	**April - May**	**April - July**	**Reduction**
Wet	76% a	73% a	0%
Medium	74% a	71% a	-26%
Dry	74% a	71% a	-42%
San Joaquin			
Wet	83% a	83% a	0%
Medium	78% a	77% a	-20%

of Nuts at bloom are determined by:

- Total # shoots
- Fraction of shoots that flower
- Number of nuts per flowering shoot

Black Butte	# Nuts	# shoots	Fraction floral	# nuts per floral shoot
Wet	0%	0%	0%	0%
Medium	-24%	-1%	-18%	-3%
Dry	-31%	-12%	-15%	-9%
San Joaquin				
Wet	0%	0%	0%	0%
Medium	-16%	3%	-15%	-1%

Overall yield effect due to all 3 factors.

shoots are composed of:

- # floral
- # vegetative
- # non-growing (dormant/dead)

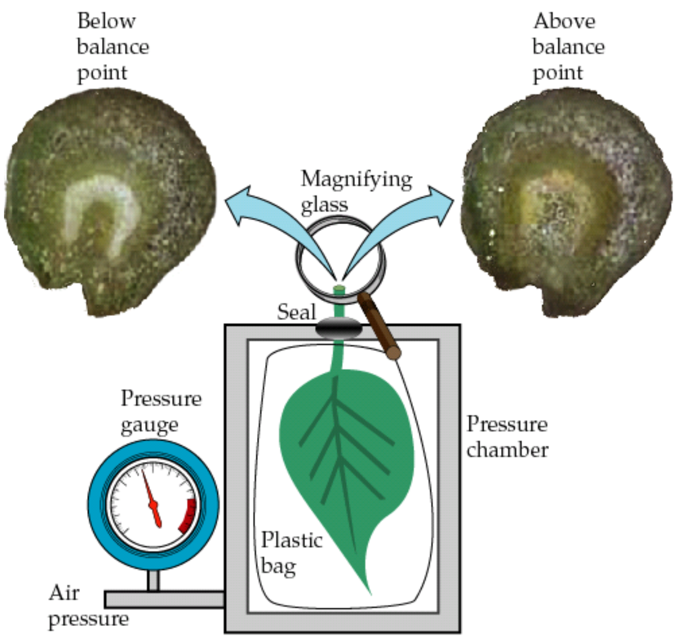
Black Butte	**Dormant**	**Floral**	**Vegetative**	**Total #**
Wet	0%	0%	0%	0%
Medium	13%	-23%	-16%	-10%
Dry	45%	-24%	-24%	-13%
San Joaquin				
Wet	0%	0%	0%	0%
Medium	19%	-16%	-14%	3%

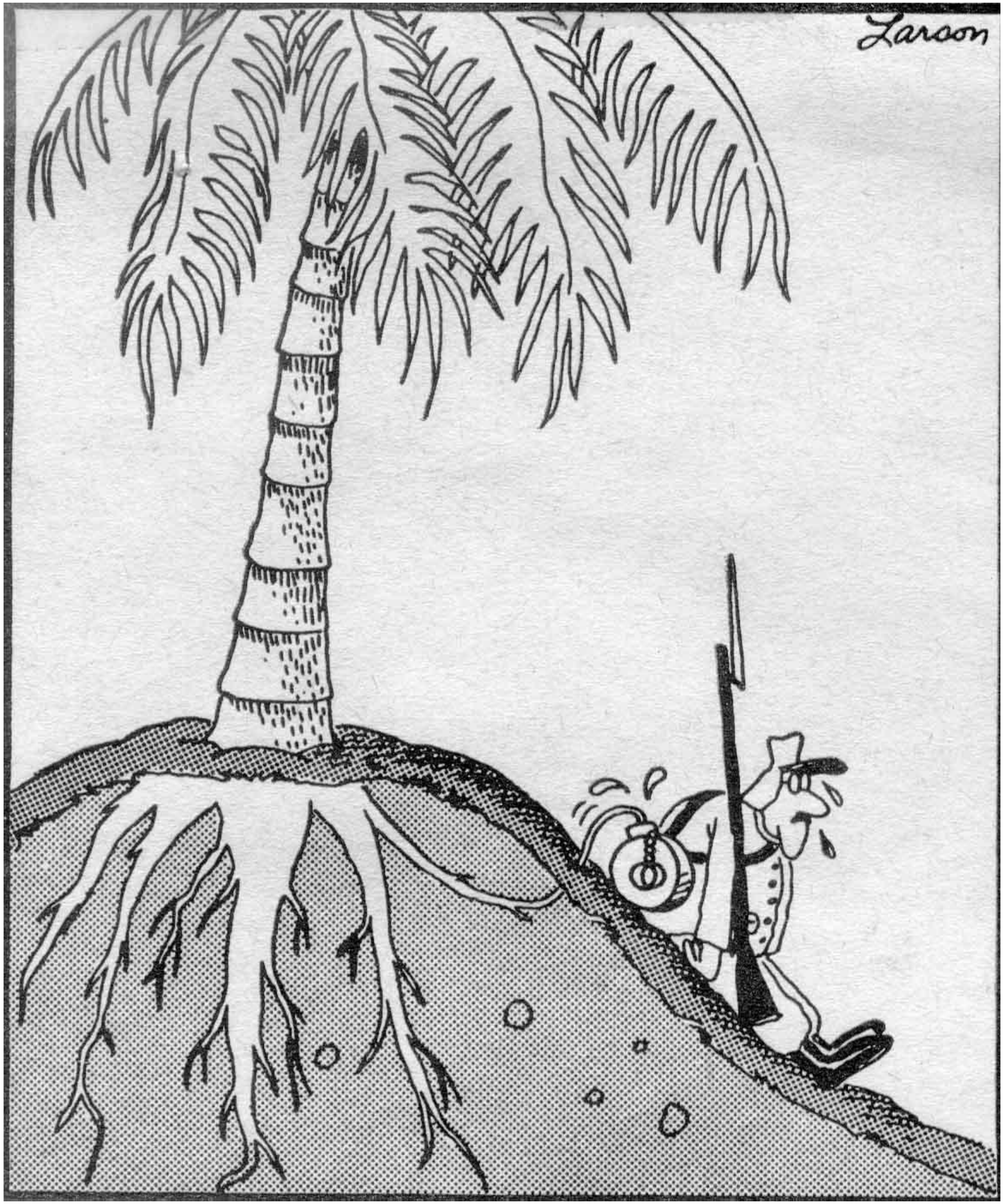
Less overall shoots, more of them dormant and less of them floral and vegetative

Conclusions

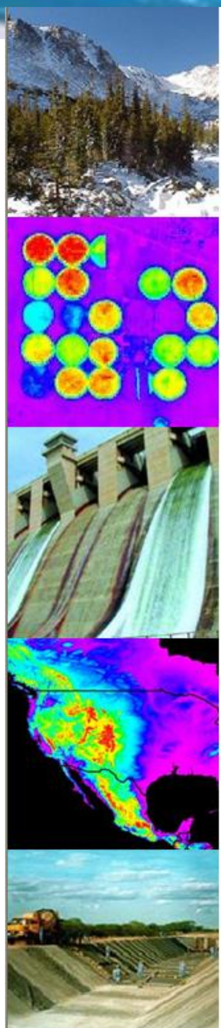
- Yield is reduced with deficit irrigation.
- Yield loss occurs in a number of factors.
- Nut size is unaffected by water stress.
- Prominent losses occur in % floral of total terminals.
- Floral and Vegetative terminals are lost and are replaced with dead/dormant terminals. Possibly an over wintering effect.

To know when plants are thirsty, you need to ask the plant





New technologies?



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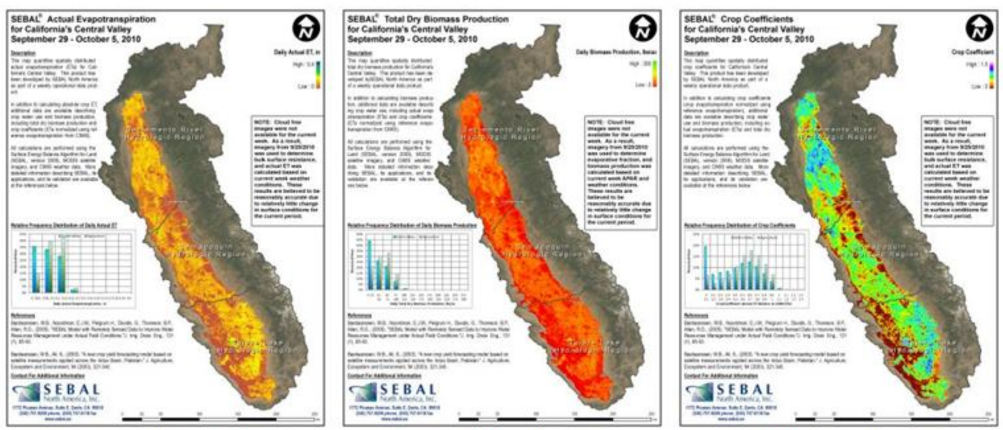
The maps of California's Central Valley provided below demonstrate the capability of SEBAL® (version 2009) as a near-real time tool for monitoring of consumptive water use and crop production. *(Click on the maps to view in higher resolution)*



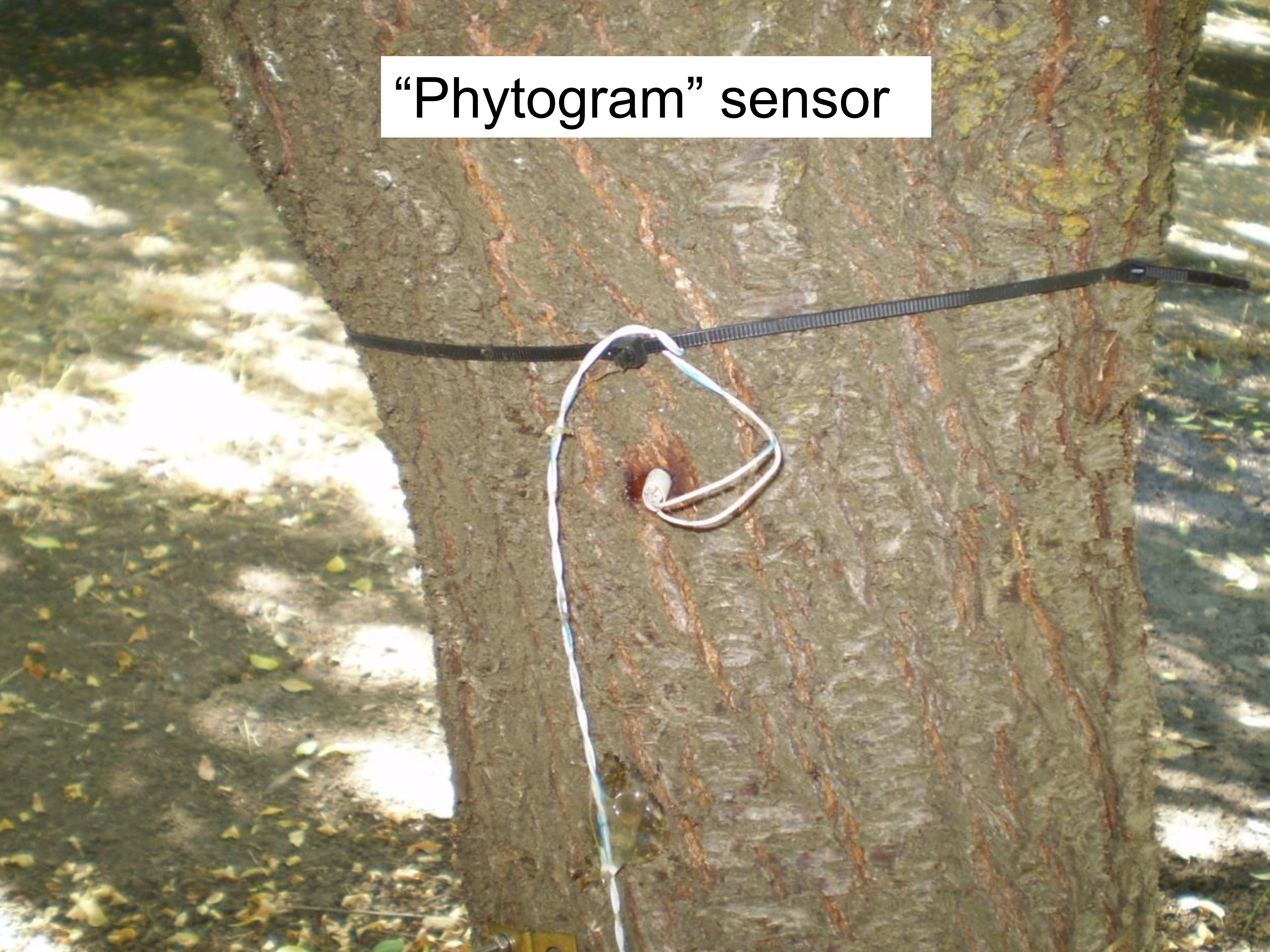
Actual Evapotranspiration | Total Dry Biomass Production | SEBAL Crop Coefficients

These maps quantify the spatial distribution and amount of actual evapotranspiration (ET), total biomass production and crop coefficients for California's Central Valley . The calculations are performed with the SEBAL® model (version 2009) using MODIS satellite imagery and CIMIS weather data.

NOTE: As of October 11, 2010, generation of the weekly operational SEBAL products for the Central Valley has been temporarily suspended. Results from 2009 and 2010 can be accessed by clicking HERE.

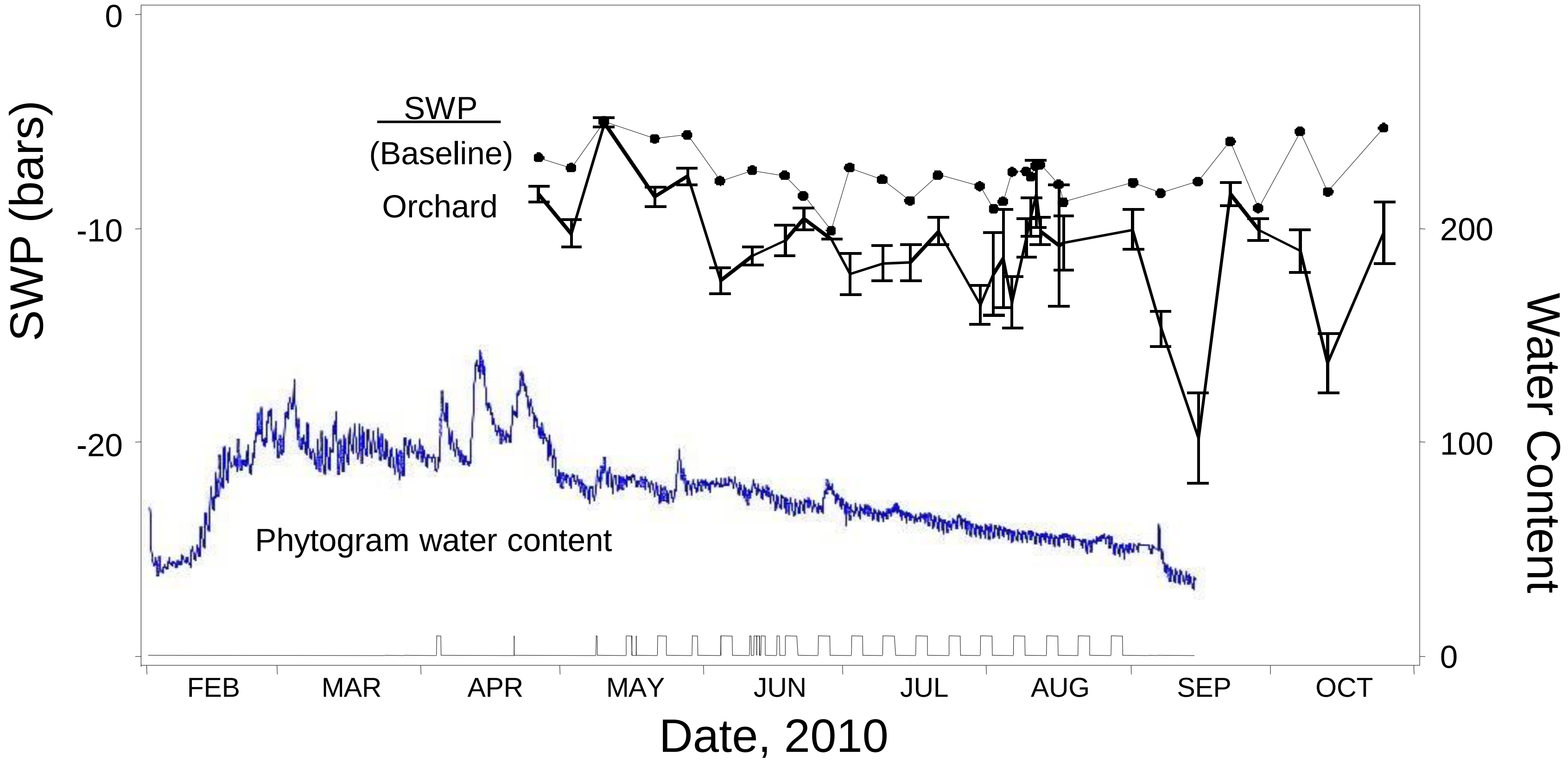
The table below summarizes the data products that are available for each week.

No.	Product	Formats	Units
1	Actual ET	Map,Table, Google Earth Overlay	Inches/day
2	Total Dry Biomass Production	Map,Table, Google Earth Overlay	Pounds/acre/day
3	SEBAL Crop Coefficients	Map,Table, Google Earth Overlay	Unitless

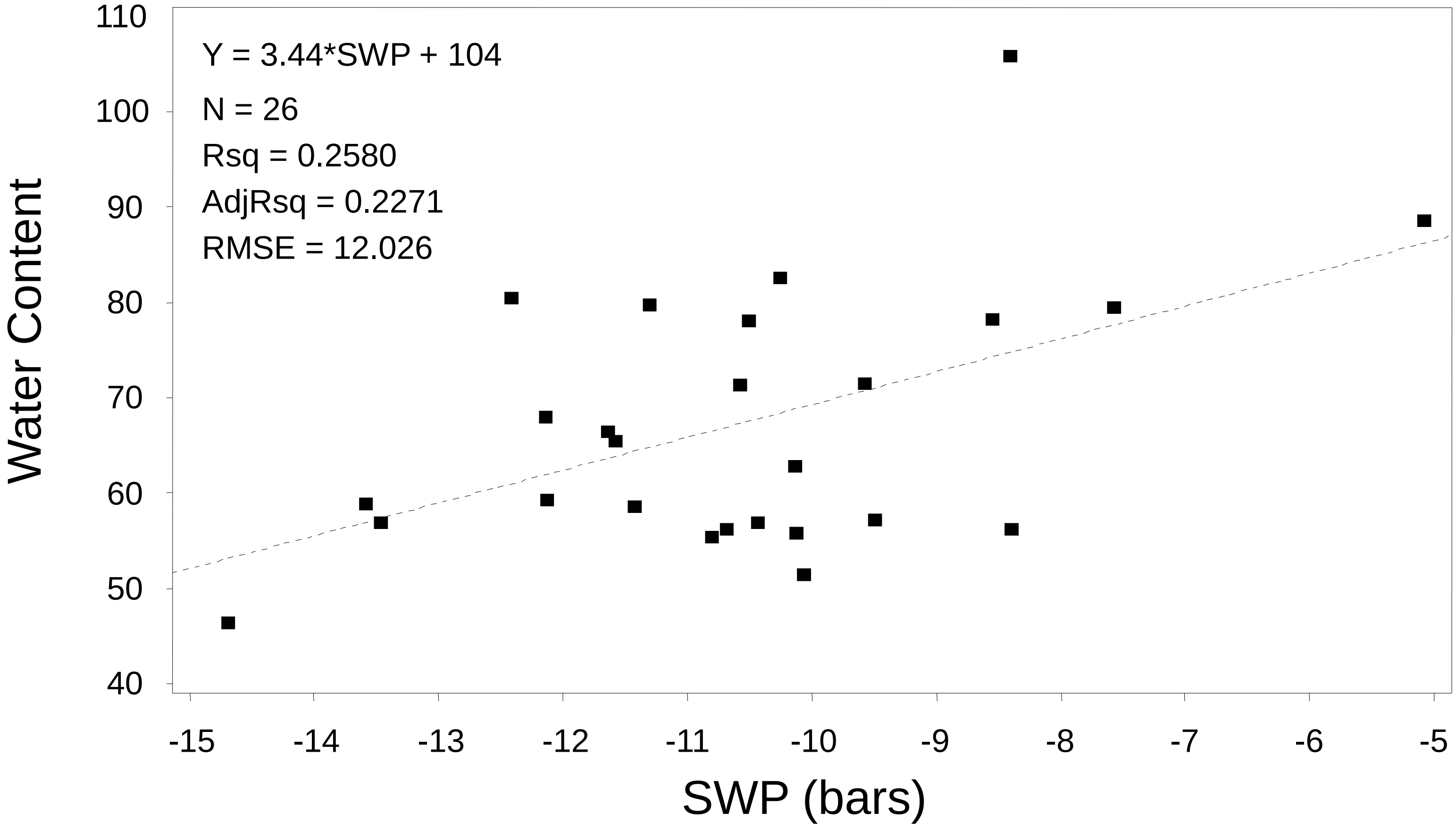

“Phytogram” sensor

“Dendrometer” sensor

Phytogram & SWP comparison



Phytogram & SWP comparison



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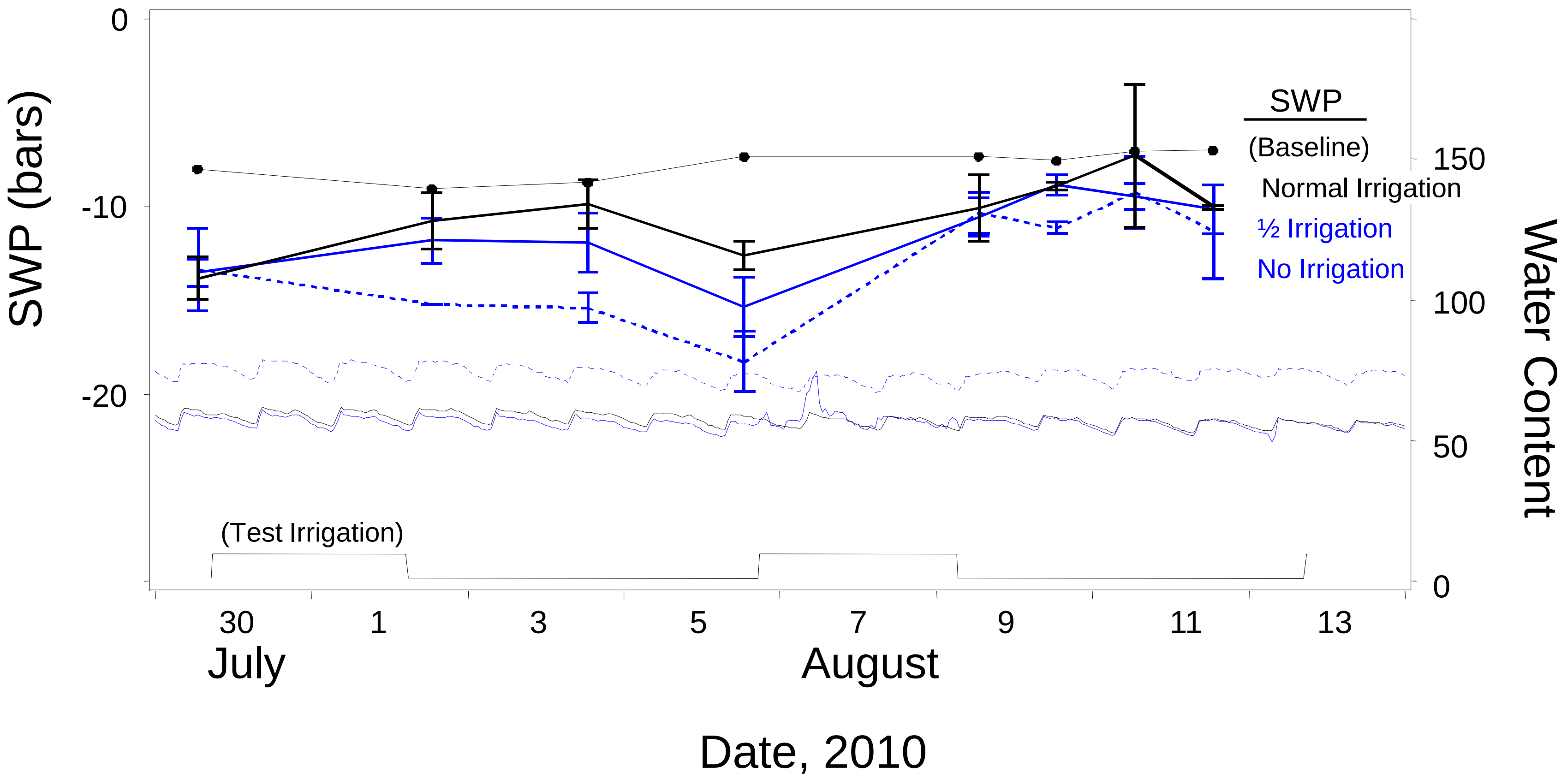
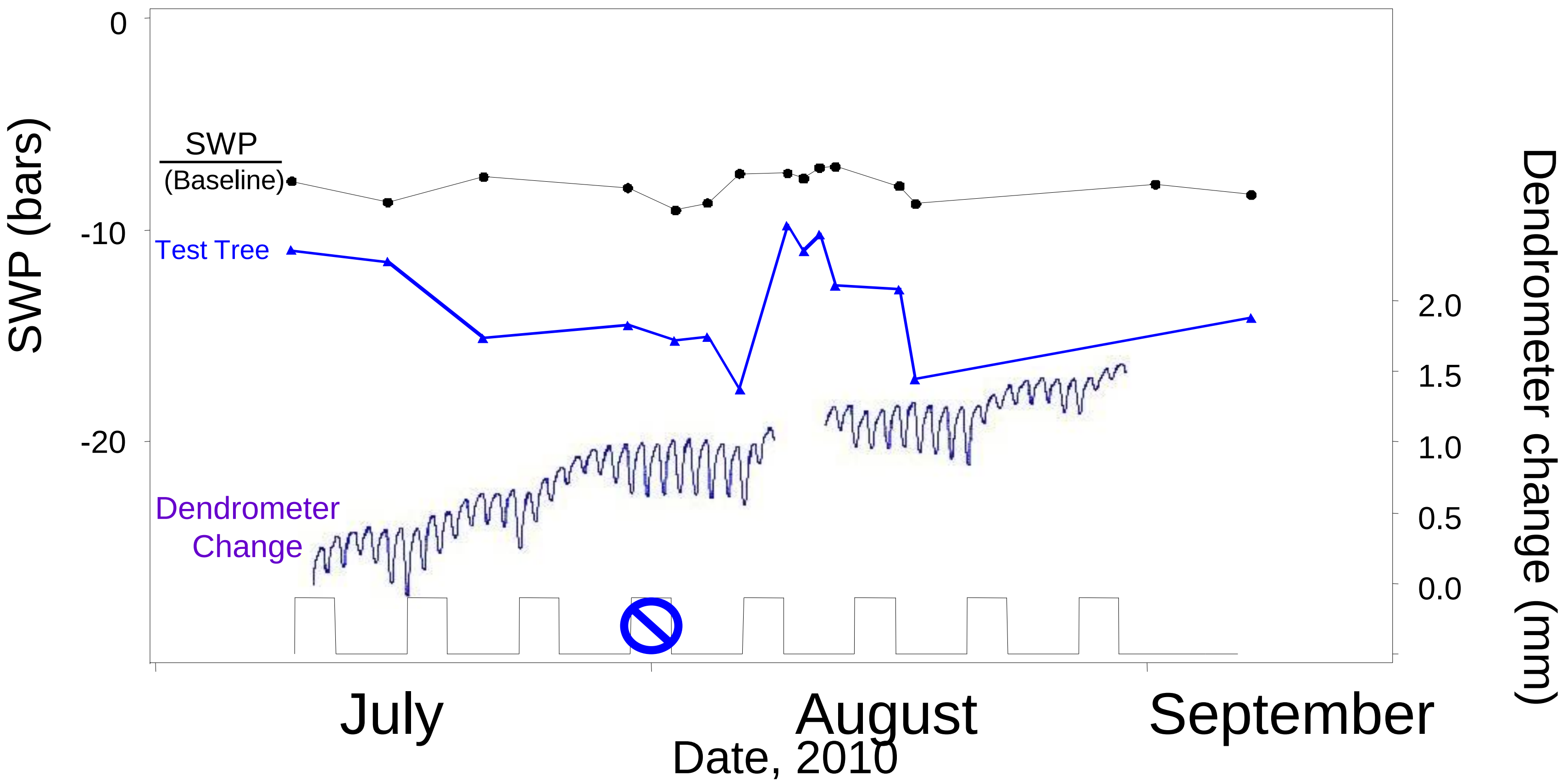
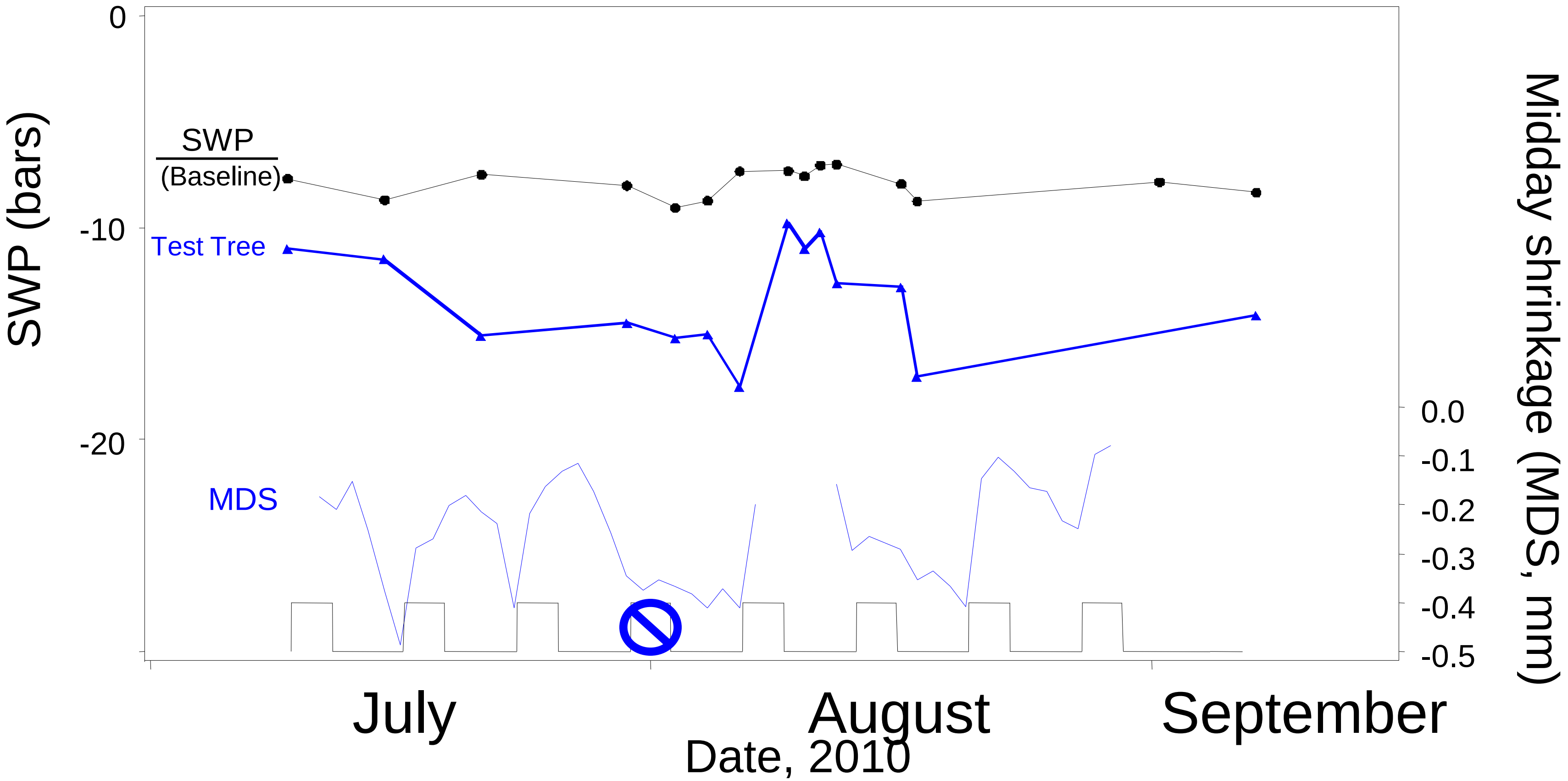


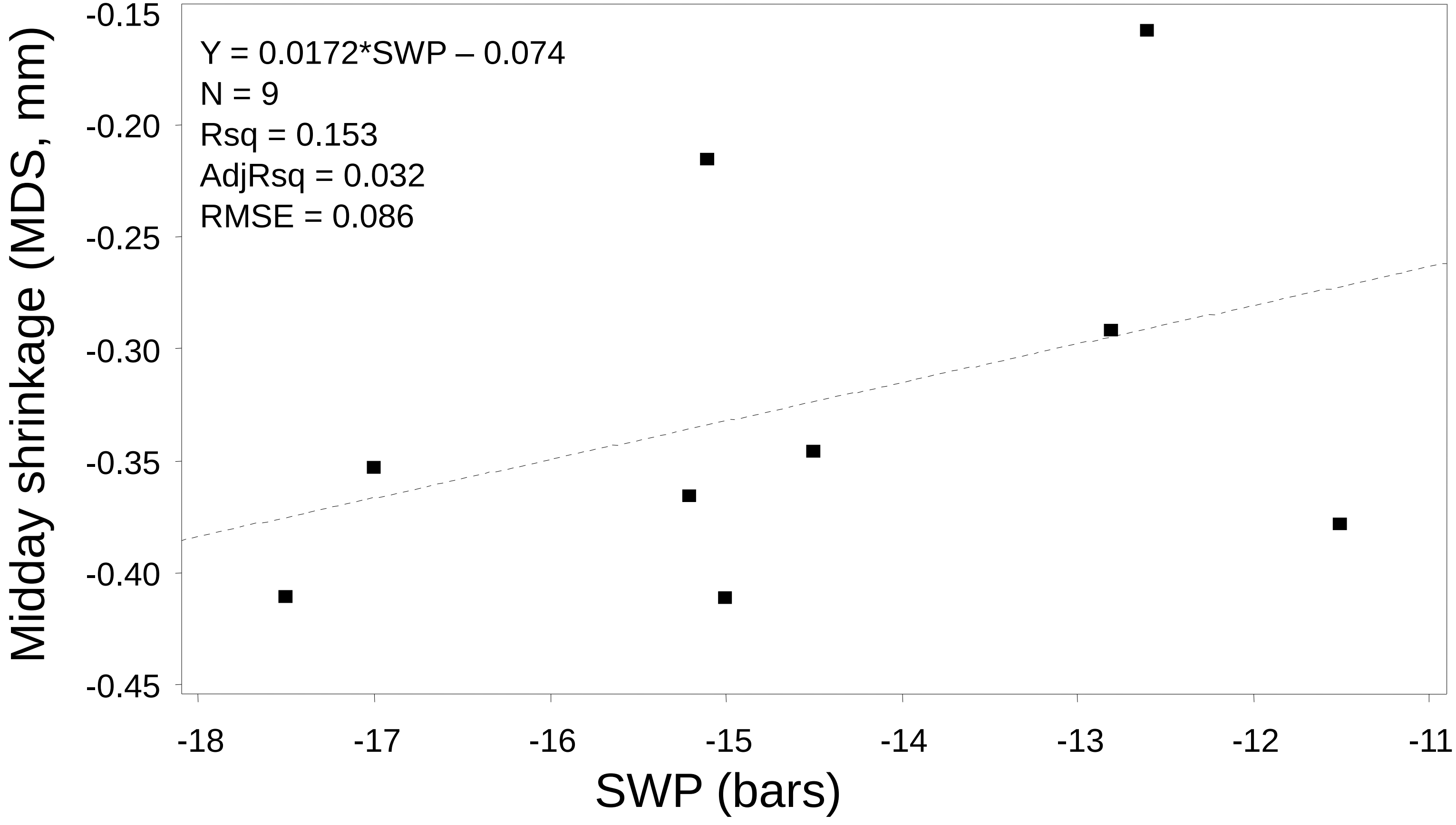
Dendrometer & SWP comparison



Dendrometer & SWP comparison



Dendrometer & SWP comparison



“Stem Hygrometer”

Main problem: temperature equilibrium and low voltage signal (need to measure temperatures to an accuracy of about 0.001C)

Sealing hygrometer with silicone