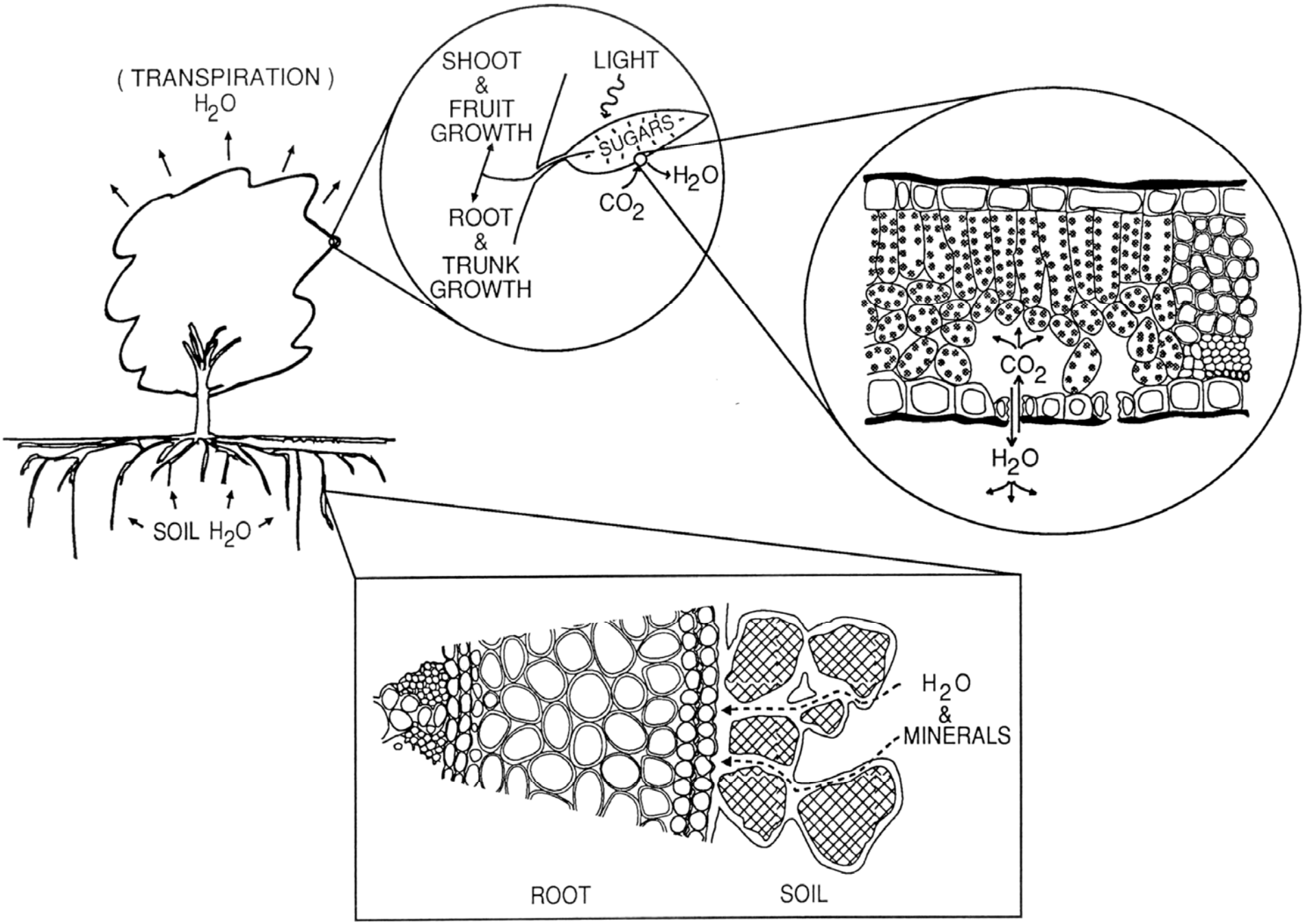
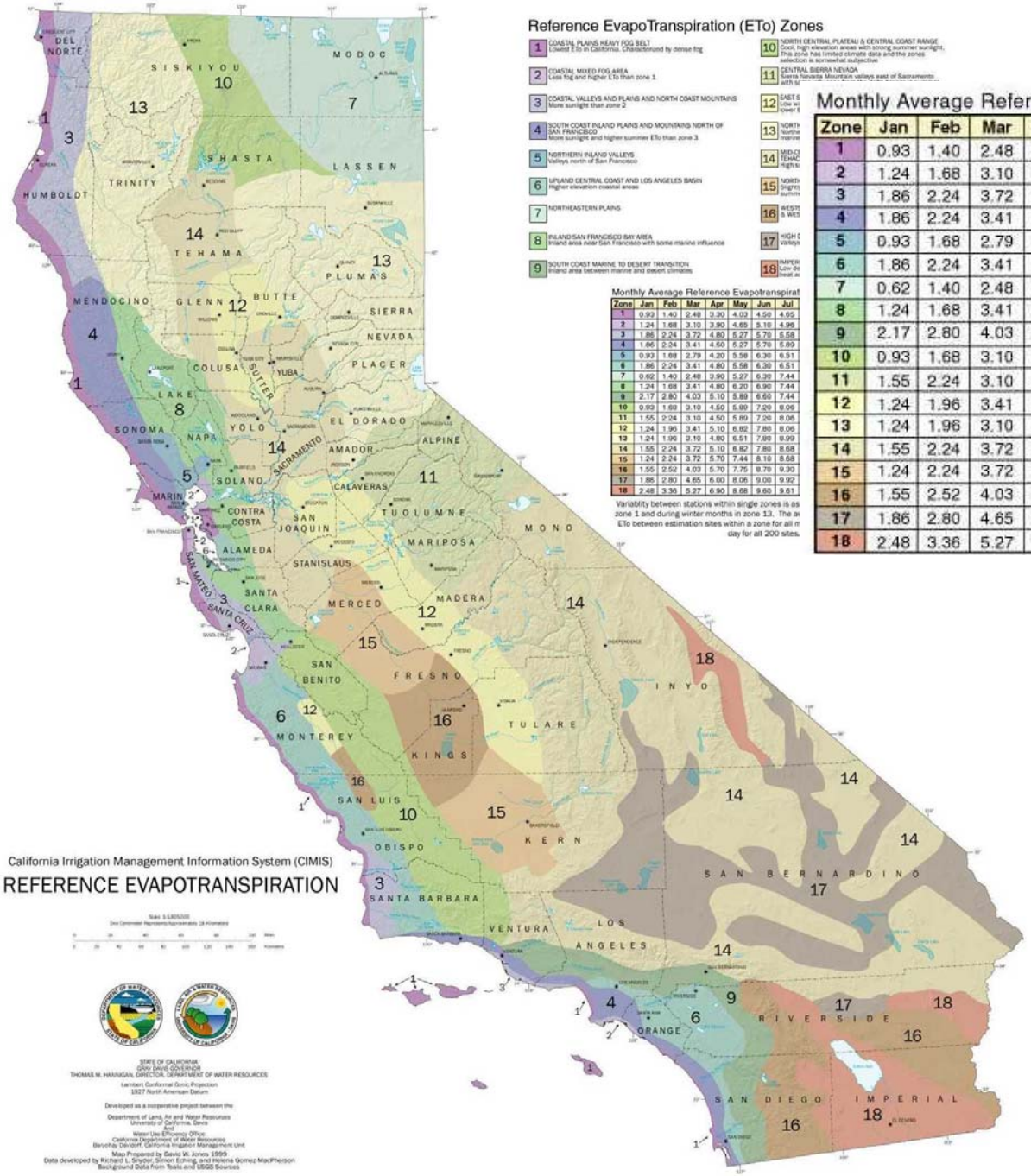
Plant Water Relations: Irrigation Advice Directly From the Tree

Ken Shackel, UCD Plant Sciences
August 4, 2009


(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



Reference EvapoTranspiration (ETo) Zones

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Monthly Average Reference Evapotranspirat

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44
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9	2.17	2.80	4.03	5.10	5.89	6.60	7.44
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30
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3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

California Irrigation Management Information System (CIMIS)

REFERENCE EVAPOTRANSPIRATION

Scale 1:1,825,200

One Centimeter Represents Approximately 18 Kilometers

Miles

Kilometers

STATE OF CALIFORNIA
GRAY DAVIS GOVERNOR
THOMAS M. HANNIGAN, DIRECTOR, DEPARTMENT OF WATER RESOURCES

Lambert Conformal Conic Projection
1927 North American Datum

Developed as a cooperative project between the:

Department of Land, Air and Water Resources
University of California, Davis
And
Water Use Efficiency Office
California Department of Water Resources
Barythia Davidoff, California Irrigation Management Unit

Map Prepared by David W. Jones 1999
Data developed by Richard L. Snyder, Simon Eching, and Helena Gomez MacPherson
Background Data from Teale and USGS Sources

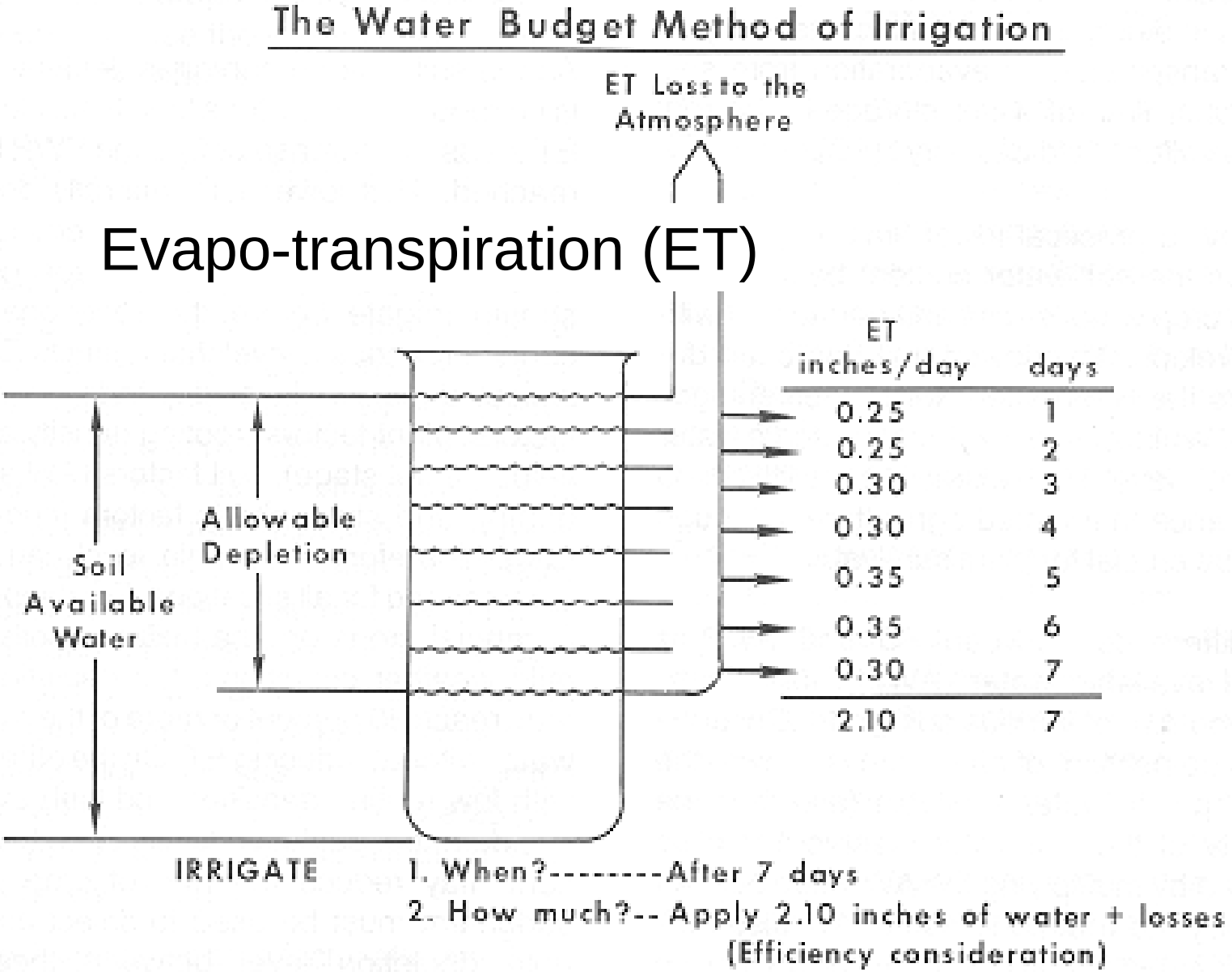
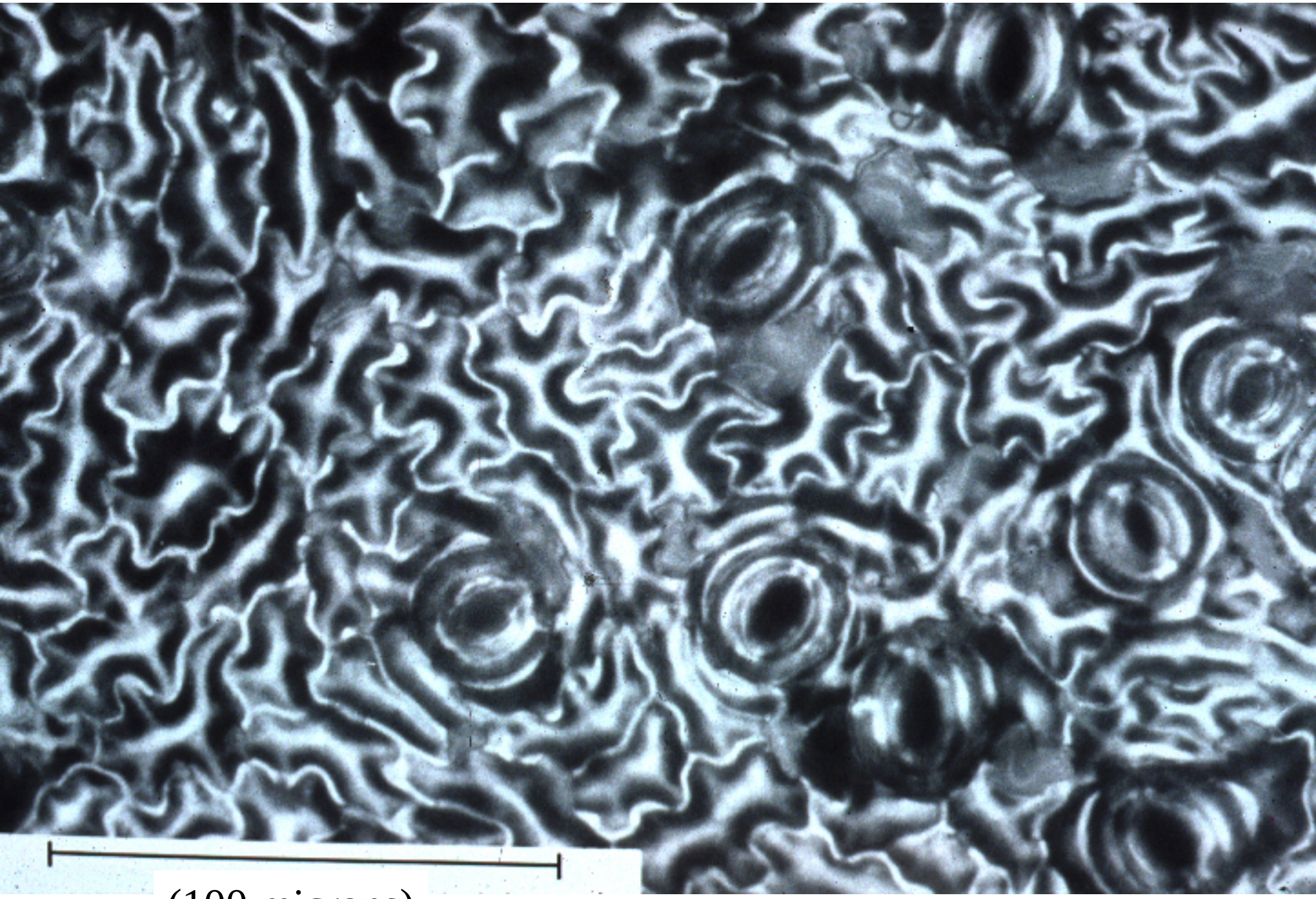


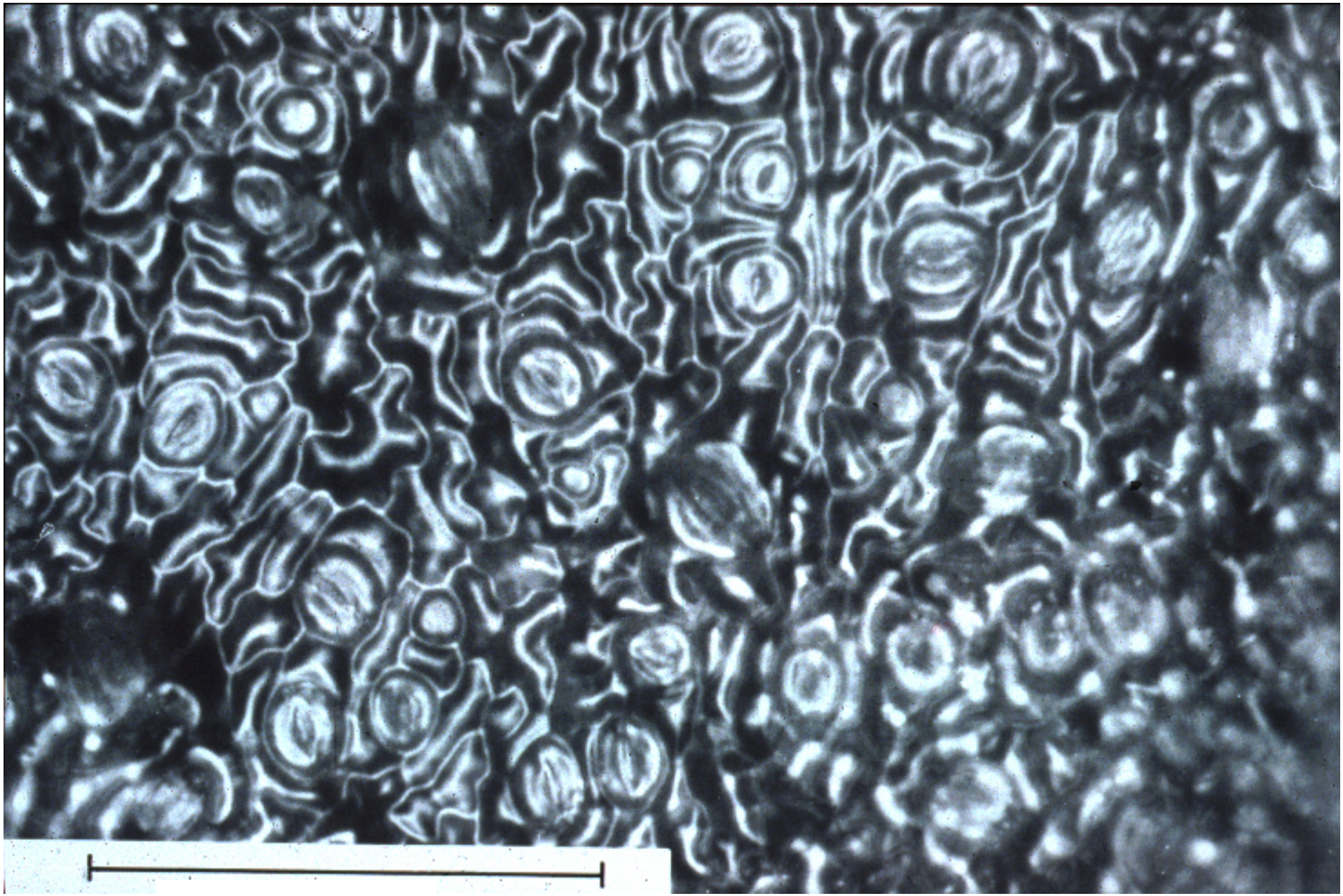
Fig. 2. Water-budget method of irrigation.

Figure 2-2 Normal (left) and wilted (right) *Coleus* plants. The normal appearance of a plant is dependent upon having sufficient water in the cells to provide turgidity. The wilted plant recovered completely after watering. Note that the youngest leaves on the wilted plant are still quite turgid.

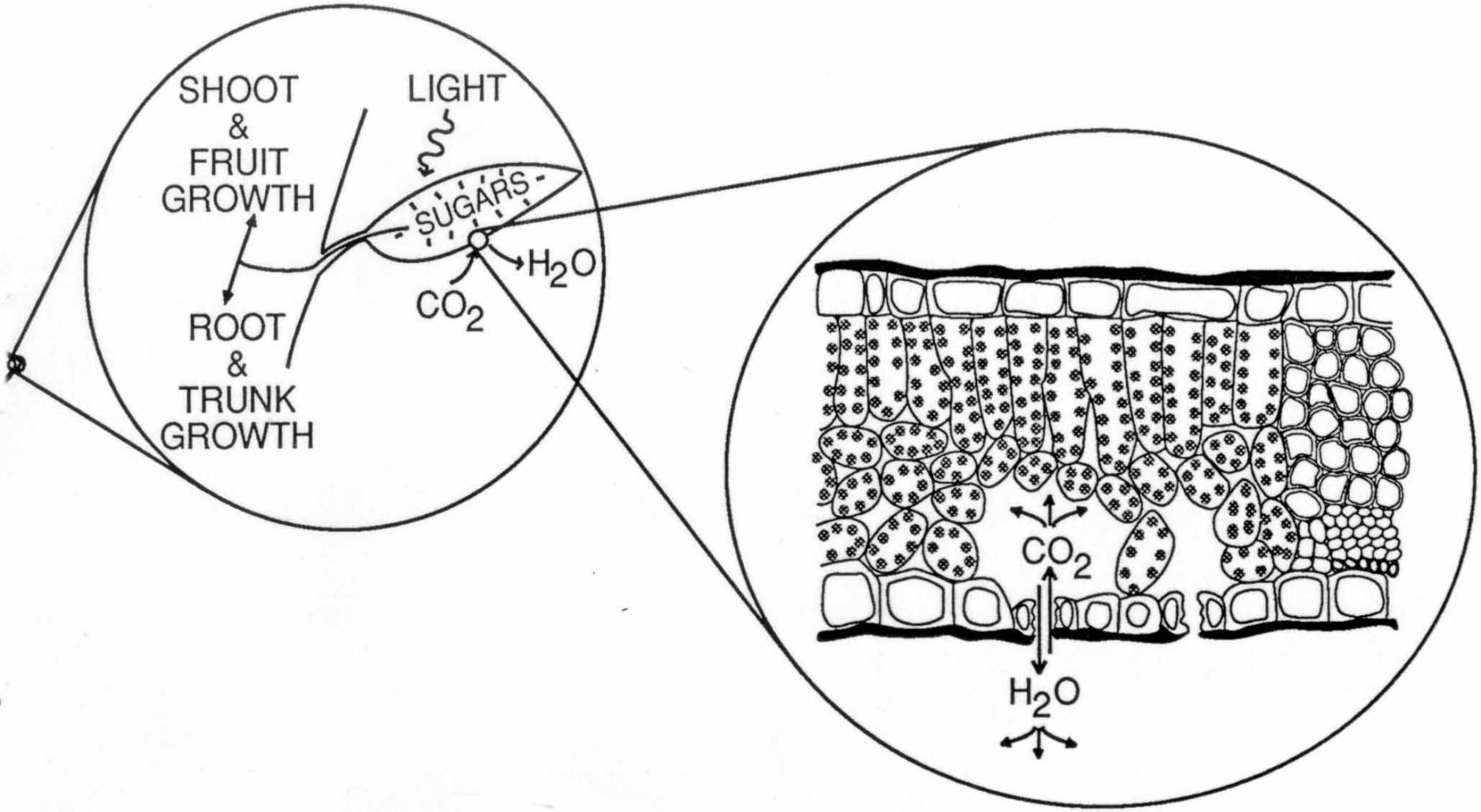
Salisbury & Ross, Plant Physiology (1992)

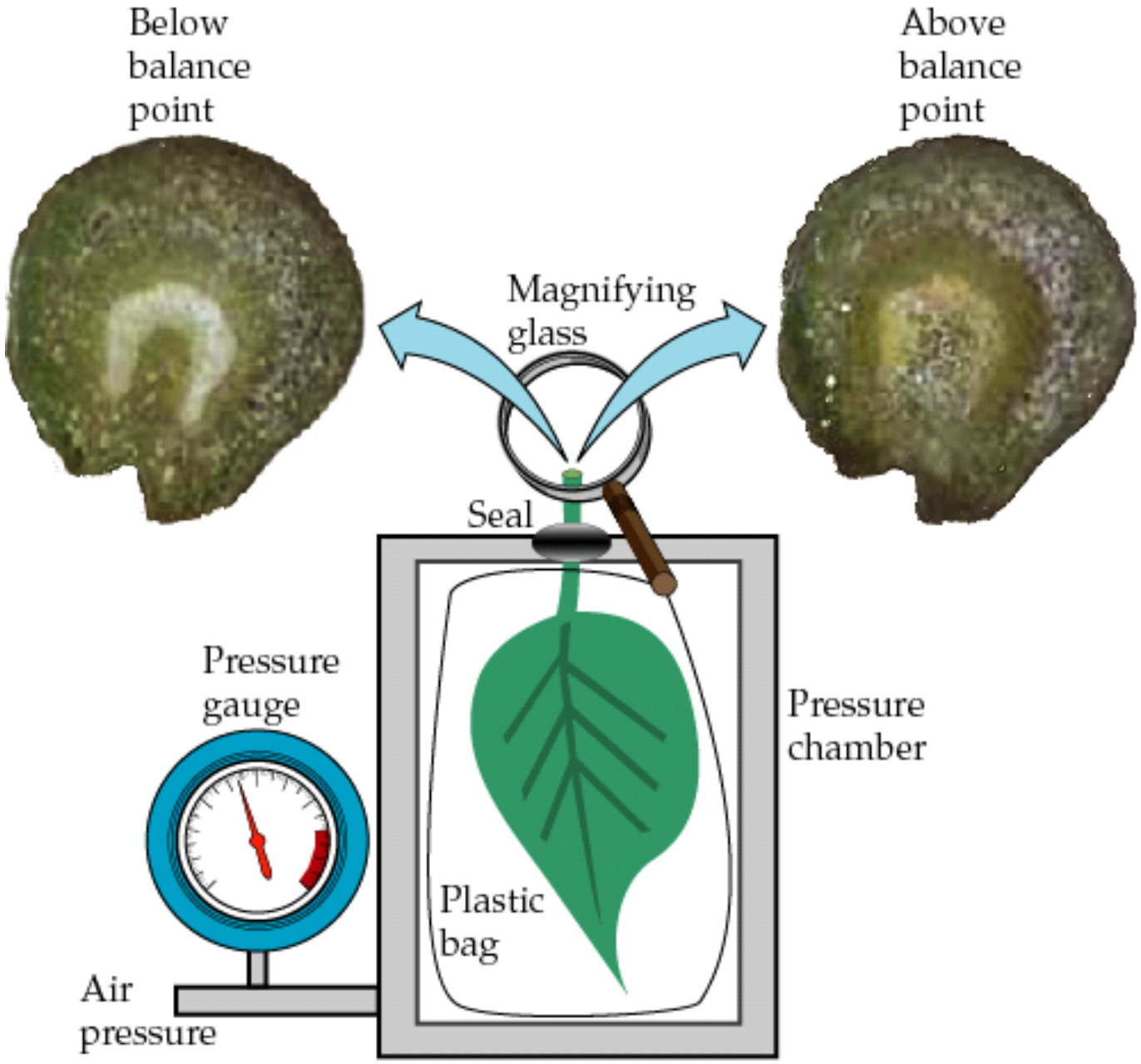


(100 microns)



(100 microns)


SHOOT
&
FRUIT
GROWTH
LIGHT
SUGARS
H_2O
CO_2
ROOT
&
TRUNK
GROWTH
CO_2
H_2O

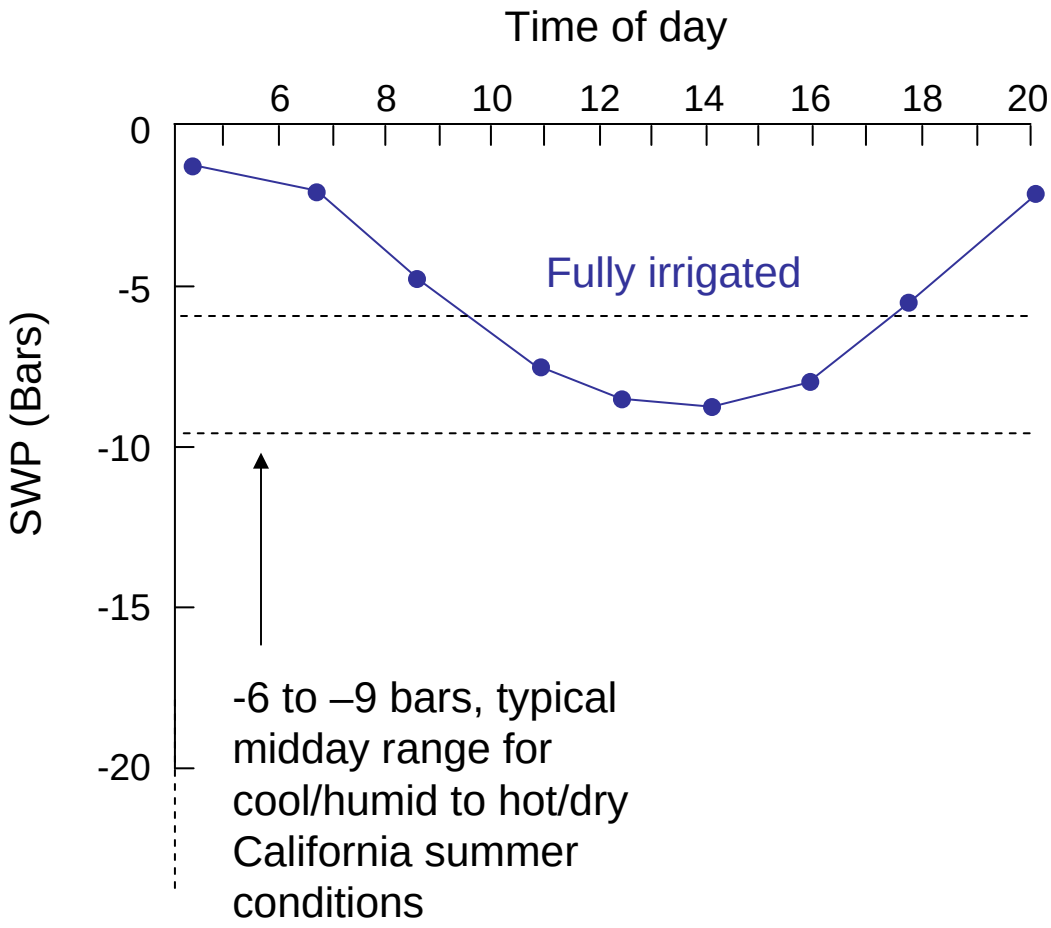

Below balance point
Above balance point
Magnifying glass
Seal
Pressure gauge
Pressure chamber
Plastic bag
Air pressure


S10
CHEVROLET
CORNING
California
E034608

Typical example of the daily pattern in SWP

Low pressure required
to see water
(LOW STRESS)

High pressure required
to see water
(HIGH STRESS)



Typical example of the daily pattern in SWP

Low pressure required
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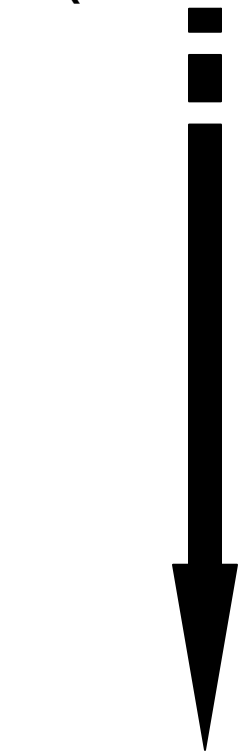
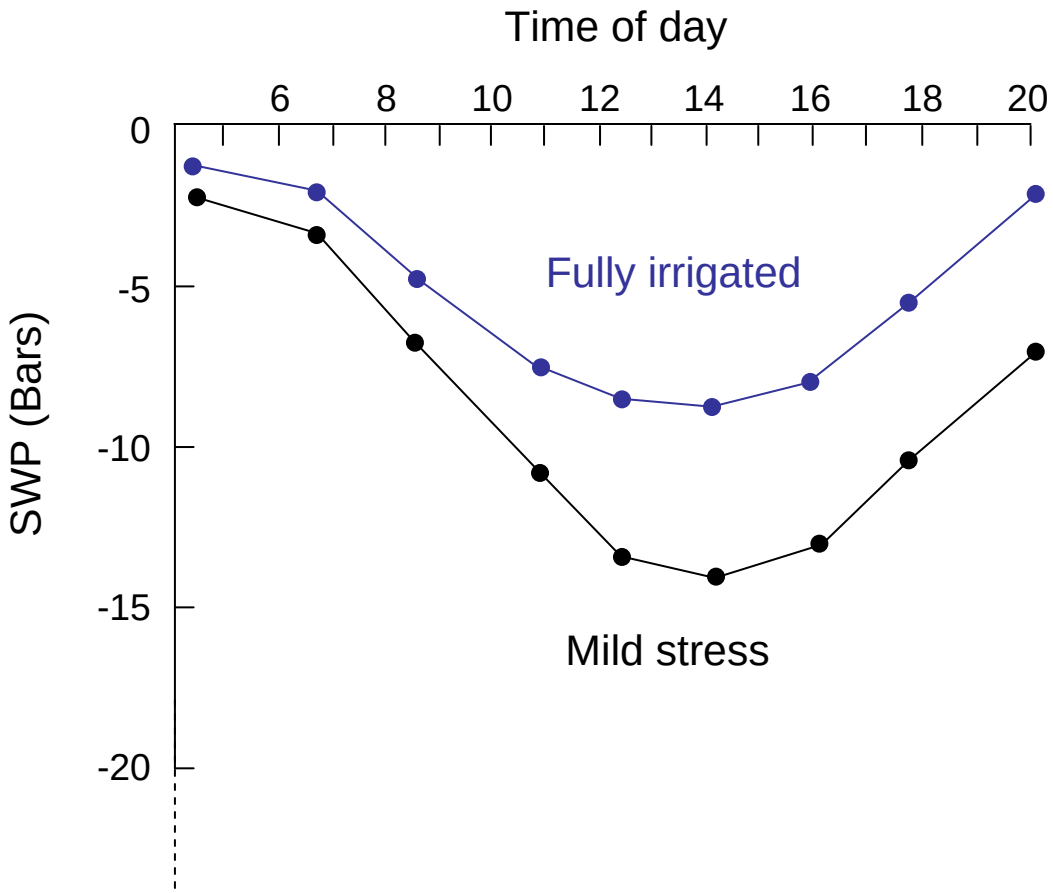
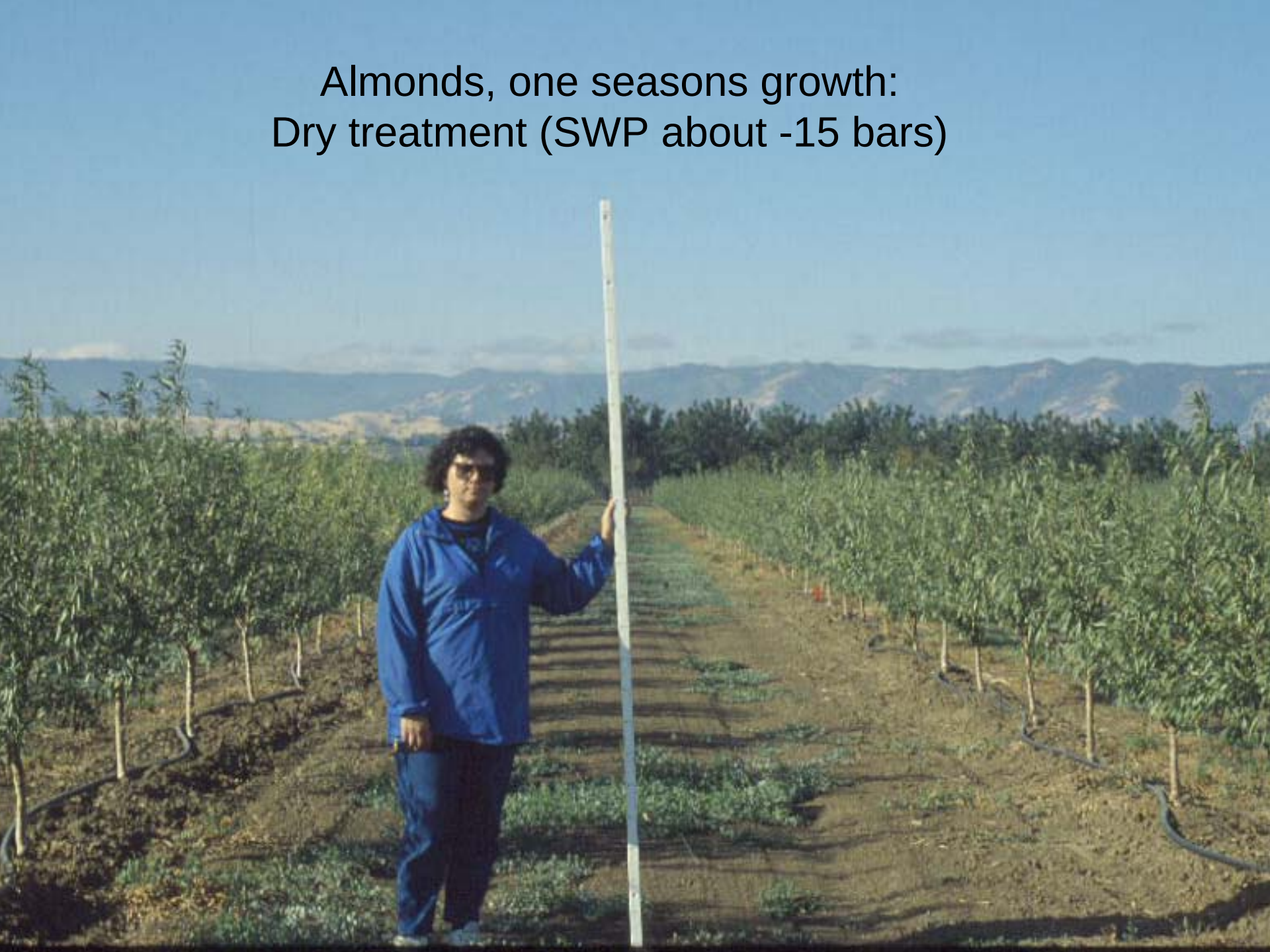


High pressure required
to see water
(HIGH STRESS)

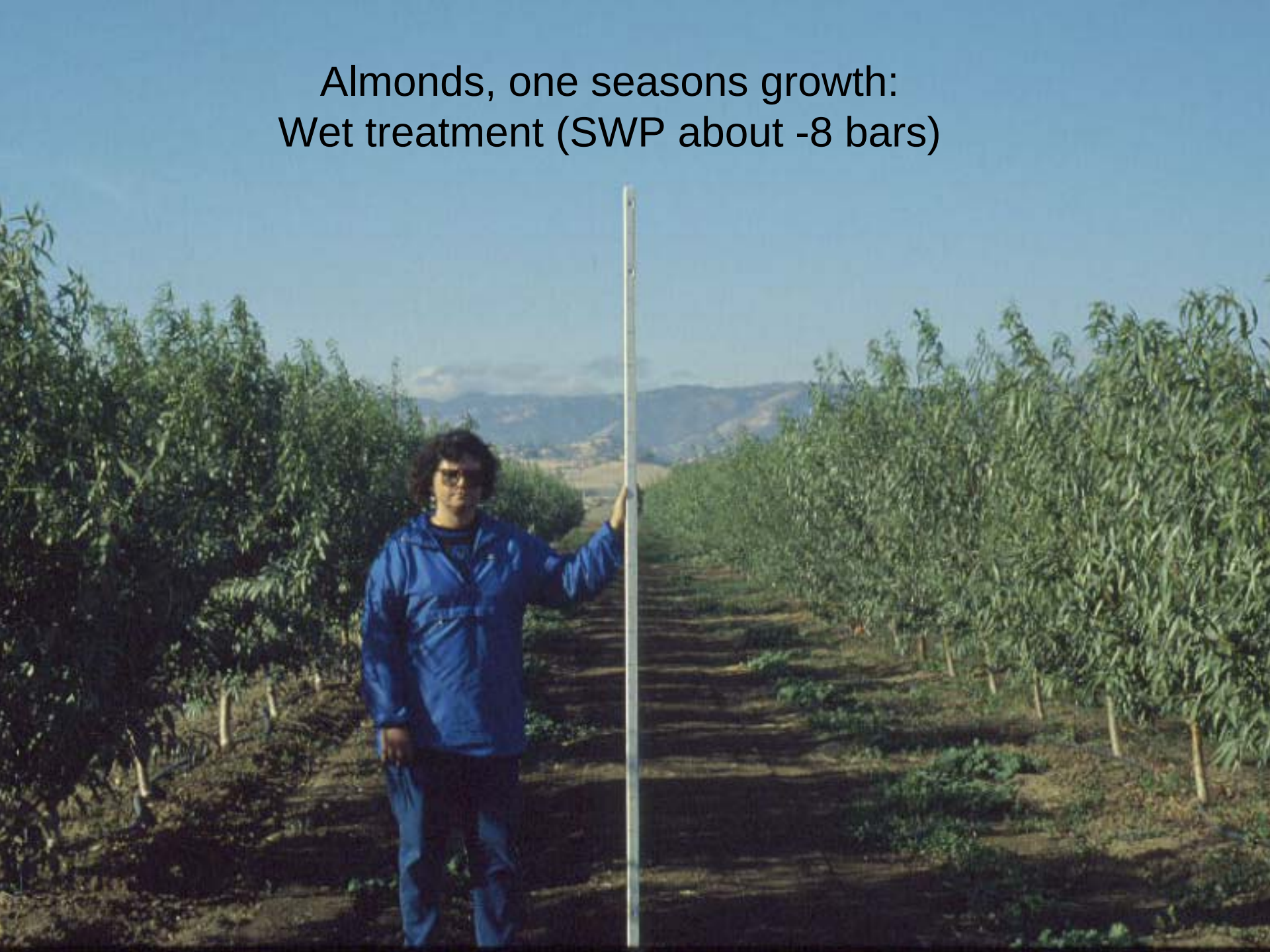


Almonds, one seasons growth:
Dry treatment (SWP about -15 bars)



Almonds, one seasons growth:
Medium treatment (SWP about -12 bars)

Almonds, one seasons growth:
Wet treatment (SWP about -8 bars)



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 prior consent by the authors.

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.

Almond hull split

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


5-9-02
WEST
(gravel)
EAST
(silt)

% Hull Split, Carmel variety

(East/West difference similar in all varieties)

	Date, 2000					
	10 Aug	16 Aug	22 Aug	31 Aug	6 Sep	14 Sep
East (Average SWP = -8.4 bars)	0%	0%	5%	13%	32%	40%
West (Average SWP = -14.1 bars)	4%	23%	60%	83%	85%	91%

Problems with uneven hull split timing:

- Uncertain timing for hull split spray
- Irrigation management problems
- Uneven/delayed harvest

NonPareil variety (Corning) – Hull Split (RDI treatment)

2001:

East (silt)

Date	JUL 13	JUL 20	JUL 27	AUG 1	AUG 13
% HS	2	20	45	70	100

West (gravel)

Date	JUL 13	JUL 20	JUL 27	AUG 1	AUG 13
% HS	2	25	55	75	100

2003:

East (silt)

Date	JUL 29	AUG 7	AUG 15	AUG 22
% HS	29	96	100	100

West (gravel)

Date	JUL 29	AUG 7	AUG 15	AUG 22
% HS	29	88	100	100

Corning location –irrigation summary (RDI)

Soil	2002		2003		2004	
	Water applied	Cutoff date	Water applied	Cutoff date	Water applied	Cutback date
East (silt)	24”	10-Jul	14”	1-Jul	18”	7-Jun
West (gravel)	40”	25-Aug	41”	4-Sep	36”	16-Sep
ETc	43”		40”		42”	

Very long cutoff/cutback OK on East (silt) soil

2001 - 2004 Almond RDI sites:

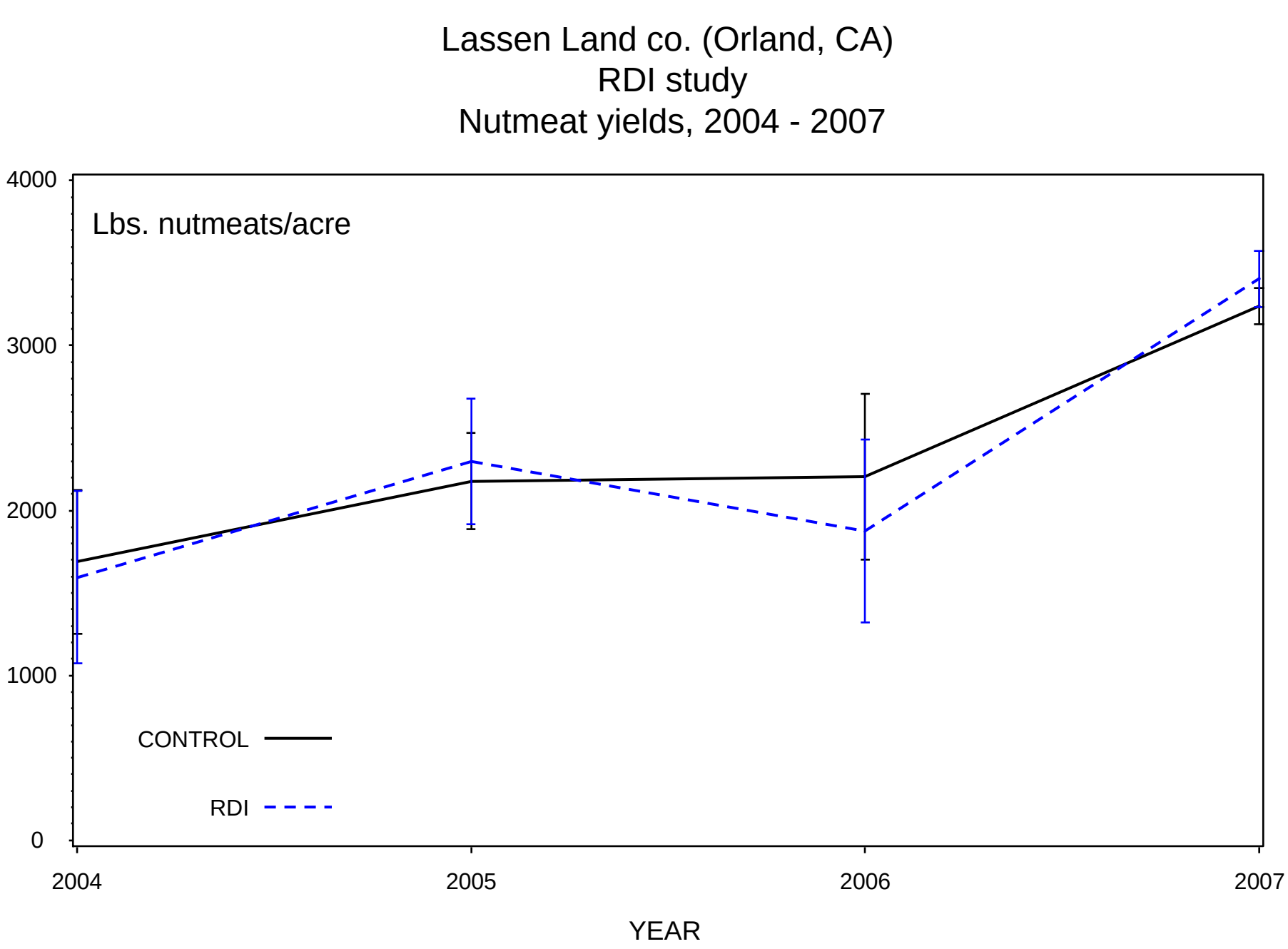
County	Location	Soil type	Age (yr)	Irrigation
Tehama	Corning(E)	Silt-Loam	9	Microsprinkler
Tehama	Corning (W)	Gravel-Loam	9	Microsprinkler
Butte	Chico	Vina-Loam	9	Solid-set Sprinkler
Colusa	Arbuckle	Gravel-Loam (II)	13	Single line drip
Solano	Dixon	Yolo-S/CLoam	8	Solid-set Sprinkler
Madera	Madera	Dinuba FSL	10	Microsprinkler
Kern	Shafter	Sandy Loam	15	Microsprinkler

Question: Can we use RDI in the same location(s) over many years without reducing yield?

Four year yield summary

(lbs. nutmeats per acre)

Treatment	2001 (2 sites)	2002 (7 sites)	2003 (7 sites)	2004 (7 sites)
Grower	2,400	3,170	2,860	2,650
RDI	2,430	3,080	2,660	2,680


Lassen Land co. (Orland, CA)
RDI study
Nutmeat yields, 2004 - 2007
Lbs. nutmeats/acre
4000
3000
2000
1000
0
CONTROL
RDI
2004
2005
2006
2007
YEAR

Benefits of RDI (mild stress) for almonds during hull split:

1) Speed up Hull Split (use water as a management tool)
2) Reduce Hull rot
3) Reduce Sticktights (Improve Harvestability)
4) Save Water
5) No negative impact on yield

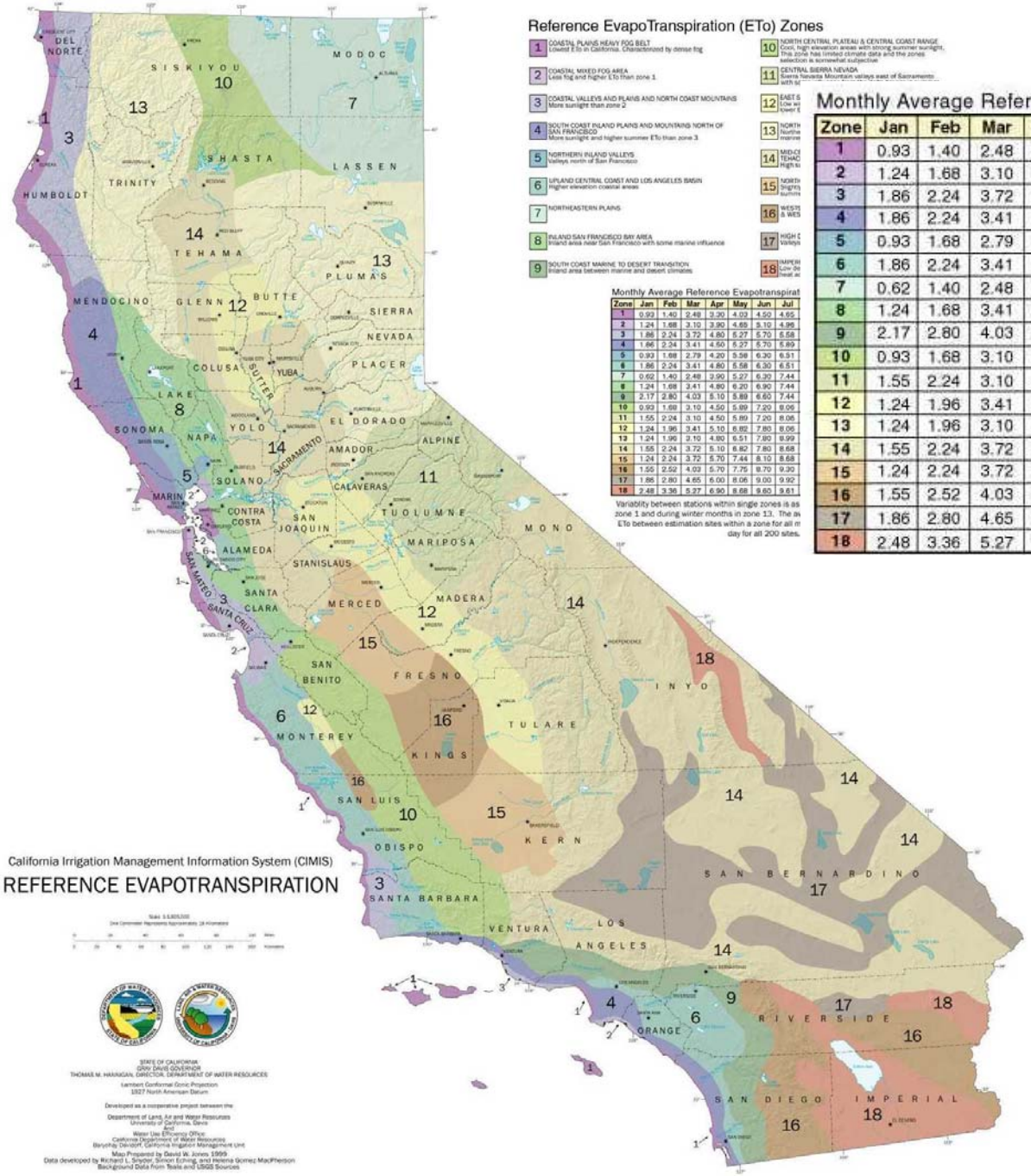
Benefits of RDI in Prunes:

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

Tehama county (Vina) prune irrigation record

(monastery site, 1999, normally irrigated every 2 weeks)

Date	Recommended	Observed	(Fully irrigated value)
April 29	-8 to –10	-6.5	(-6.8)
May 6		-7.2	(-6.4)
May 12		-8.5	(-7.3)
May 18		-8.6	(-5.7)
May 20	IRRIGATE		
May 25	-8 to –10	-5.5	(-6.7)
June 4 (rain June 2)		-5.4	(-5.5)
June 10 (...June 24)		-7.4	(-8.2)
July 1	-10 to –12	-10.4	(-9.4)
July 2	IRRIGATE		
July 13 (...July 27)	-10 to –12	-8.4	(-9.2)
August 2	-12 to -14	-10.1	(-7.2)
August 5	IRRIGATE		
August 9 (...August 23)	-12 to –14	-8.0	(-8.0)
August 30		-10.5	(-6.7)
Mid-September	HARVEST		
September 24	IRRIGATE		
September 27	-14 to -18	-6.7	(-6.7)



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2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

California Irrigation Management Information System (CIMIS)

REFERENCE EVAPOTRANSPIRATION

Scale 1:1,825,200

One Centimeter Represents Approximately 18 Kilometers

Miles

Kilometers

STATE OF CALIFORNIA
GRAY DAVIS GOVERNOR
THOMAS M. HANNIGAN, DIRECTOR, DEPARTMENT OF WATER RESOURCES

Lambert Conformal Conic Projection
1927 North American Datum

Developed as a cooperative project between the:

Department of Land, Air and Water Resources
University of California, Davis
And
Water Use Efficiency Office
California Department of Water Resources
Barythia Davidoff, California Irrigation Management Unit

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Background Data from Teale and USGS Sources