UNIVERSITY of CALIFORNIA
COOPERATIVE EXTENSION

Water and Fertigation Management in Almonds

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http://cekern.ucdavis.edu/Irrigation_Management/

19TH ANNUAL FERTILIZER RESEARCH AND EDUCATION PROGRAM & WESTERN PLANT HEALTH ASSOCIA-TION CENTRAL VALLEY NUTRIENT SEMINAR

Tulare CA Nov. 16-17, 2011

Almond Nutrition/ET Collaborative Projects

Field Calibration of Surface Renewal ET – Updated Crop coefficients for CA: 2007-2009 (CA Dept of Water Resources)

Refined Crop Coefficients to Improve Water Resources Planning and Management: 2008-2009 (CA Dept of Water Resources)

Development of a Nutrient Budget Approach To Fertilizer Management In Almond: 2008-2012

Fertigation: Case study of interaction of water and nutrient management in almonds: 2008-2012

Advanced sensing and management technologies to optimize resource use in specialty crops: case studies of water and nitrogen in deciduous crops under normal and resource-limited conditions: 2009-2012 (USDA Speciality Crops Research Initiative)

Optimization of water use and nitrate use for almonds under micro-irrigation: 2010-2012

Almond orchards and greenhouse gases: calculating nitrous oxide emissions from two N fertilizer and two micro-irrigation systems: 2008-2012

Cooperating Researchers/Agencies/Companies:

- Rick Snyder (UCD), Allan Fulton (UCCE, Butte) Dan Munk (UCCE Fresno), DWR (**Almond ET**)
- Patrick Brown, Sebastian Saa Silva, Saiful Muhammad (UCD, **Tree nutrition**)
- Ken Shackel, Bruce Lampenin, Mike Whiting (UCD), above and many others, NASA (**Tree stress and remote sensing**)
- Dave Smart, Daniel Shellenberg, above UCD (**NOx emissions and N fertilizer efficiency**)
- PARAMOUNT FARMING COMPANY
- FUNDING: YARA, HAIFA, SQM FERTILIZER COMPANIES, ALMOND BOARD of CA, CDFA-FREP, DWR

In-kind: PureSense, Grundfos, Bowsmith, Irrometer

- **ESSENTIAL** ***water/fertigation for almonds***

1 : something basic <the essentials of astronomy>

2 : something necessary, indispensable, or unavoidable

(Merriam-Websters Dictionary)

3 : Making 4,000 lb/ac nut meats!

(Westside Almond Growers)

SO WHAT'S the ESSENTIAL WATER & FERTIGATION SYSTEM for MAKING 4,000 lb/ac?


"Essential" is just the basics, right?
So can flood irrigation with 8 inch
alfalfa valves @ 200 gpm be optimal?


What about 18 inch
valves @ 2000 gpm?

Micro-irrigation system capable of injecting fertilizer and applying 0.6 to 1.5 inches/day


… or do you need this
kind of system …

… and this much technology?

YES …

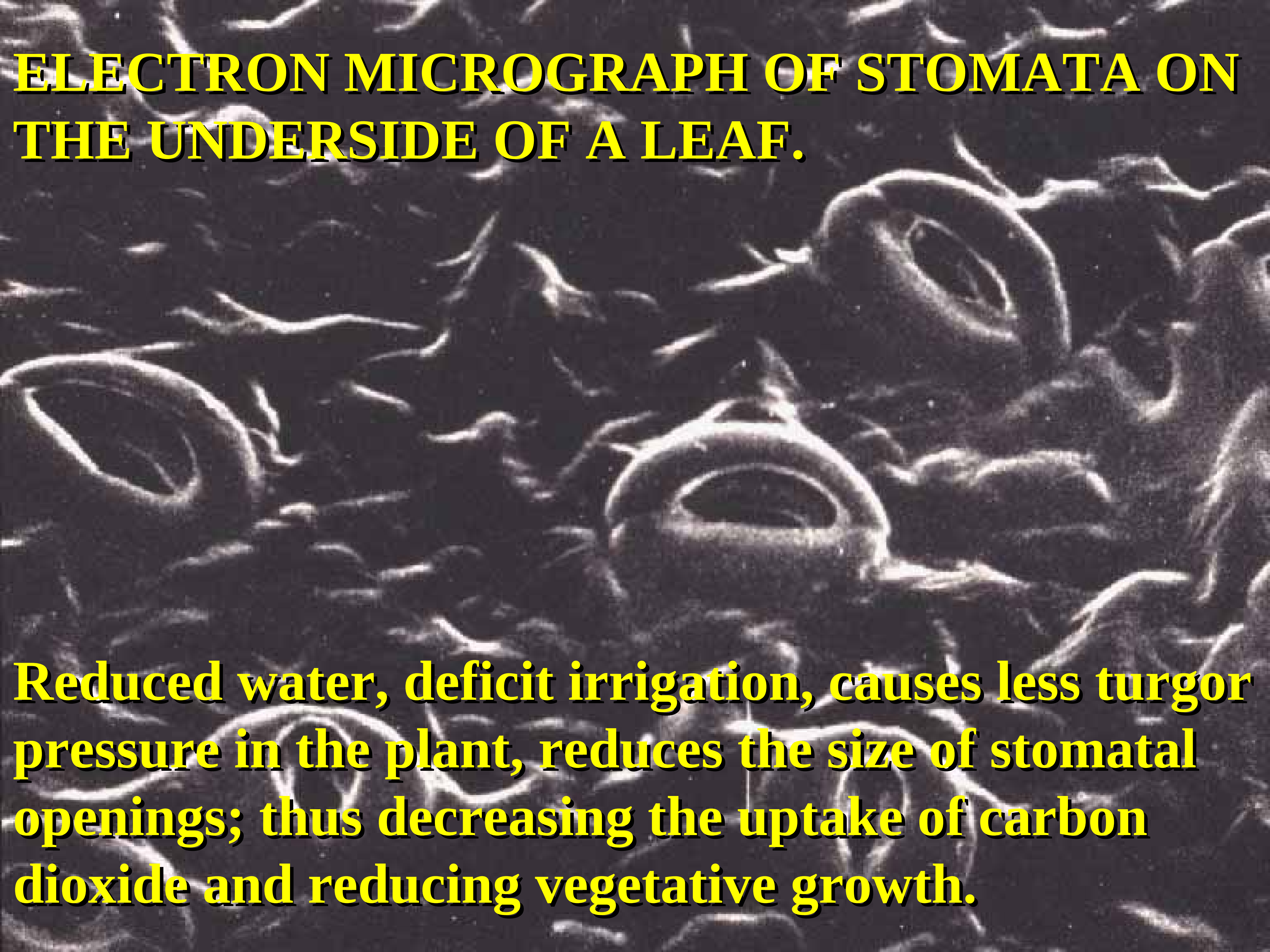
NO …

DEPENDS.

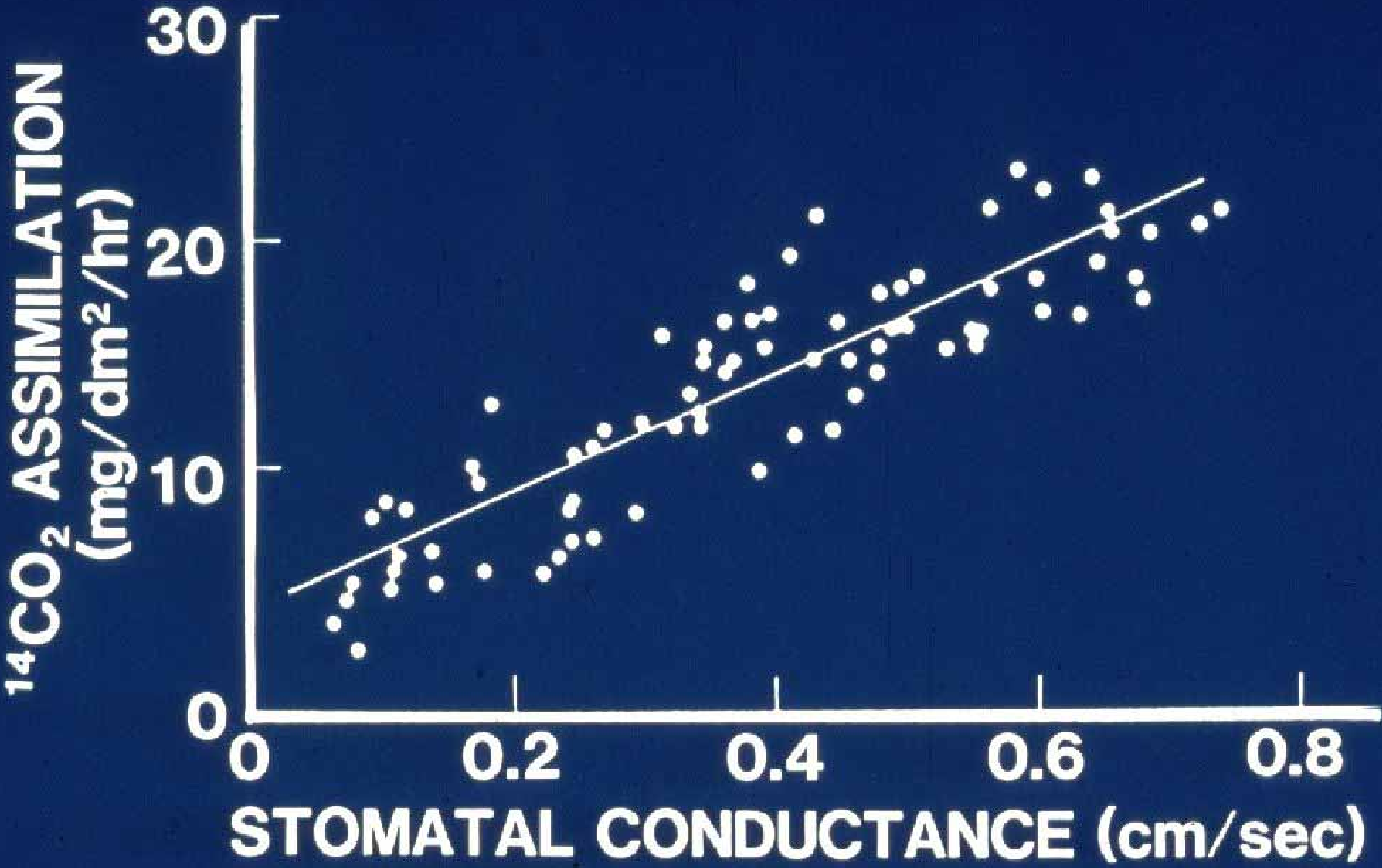
What's the critical process that keeps the crop growing?

- **Optimal photosynthesis**
- **Maximum carbon dioxide uptake**

ELECTRON MICROGRAPH OF STOMATA ON THE UNDERSIDE OF A LEAF.



Reduced water, deficit irrigation, causes less turgor pressure in the plant, reduces the size of stomatal openings; thus decreasing the uptake of carbon dioxide and reducing vegetative growth.



$^{14}CO_2$ ASSIMILATION (mg/dm^2/hr)
30
20
10
0
0
0.2
0.4
0.6
0.8
STOMATAL CONDUCTANCE (cm/sec)

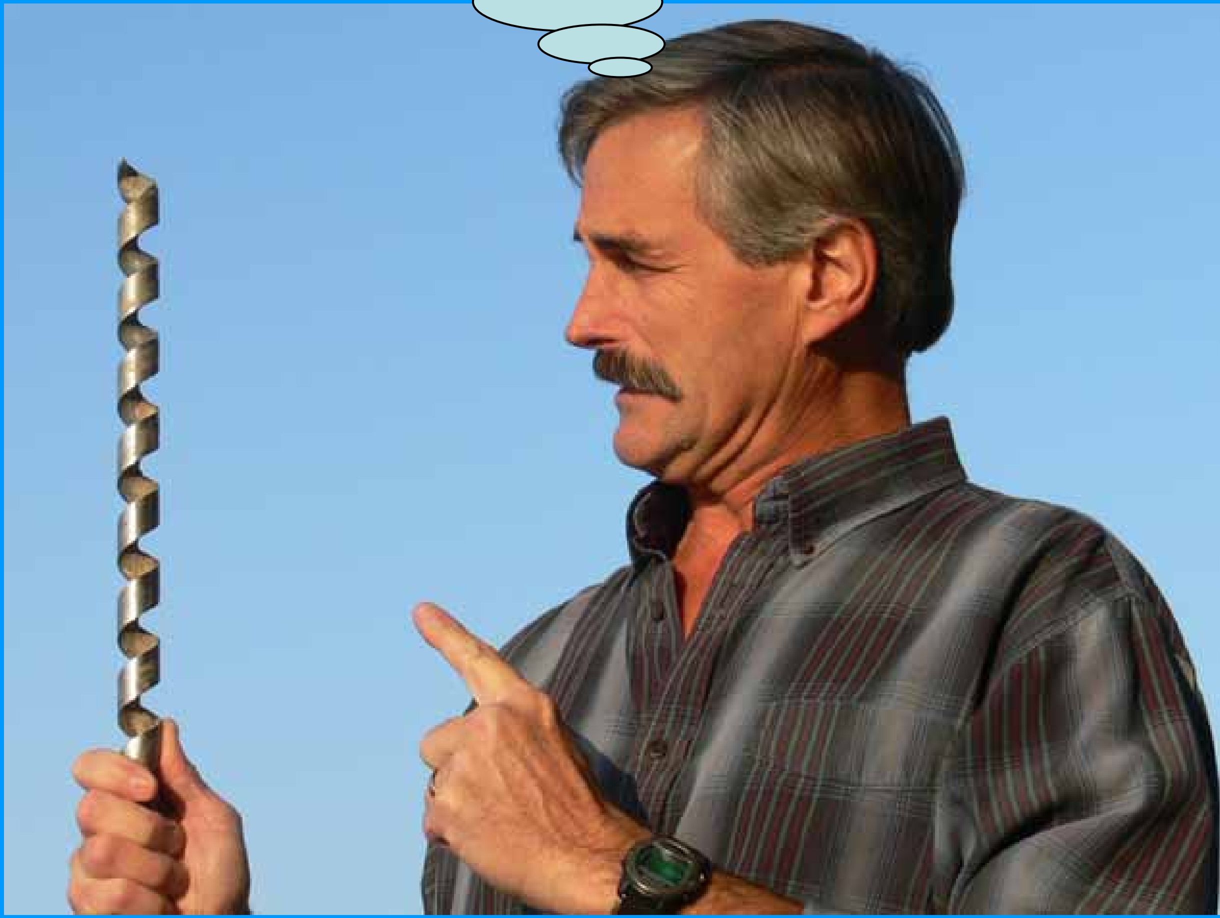
<u>So Point 1:</u> a public service reminder …

(1st leaf almonds needing to grow as much vegetative matter as possible)

This is your crop.

This is your crop
on reduced water.

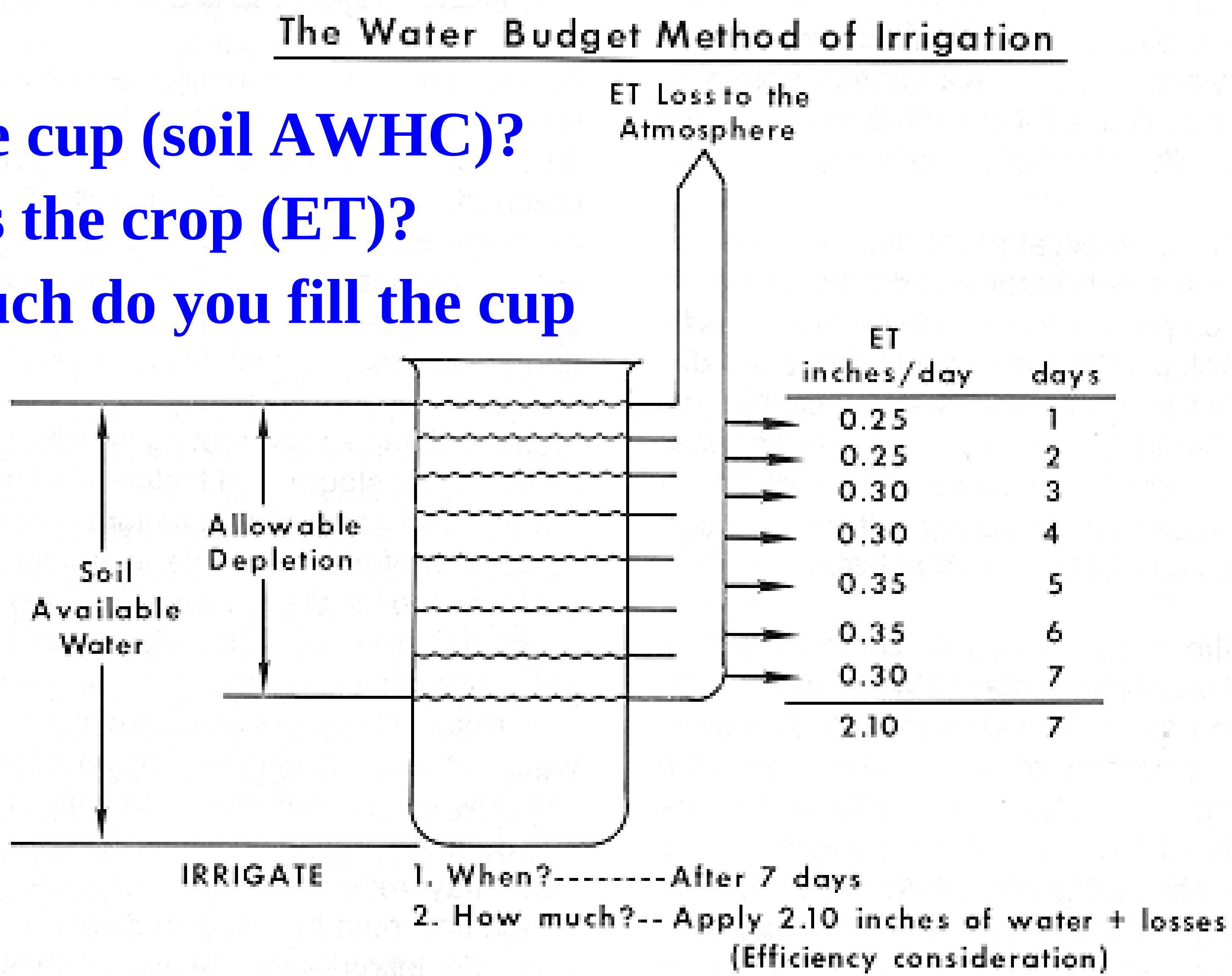
I’m screwed!



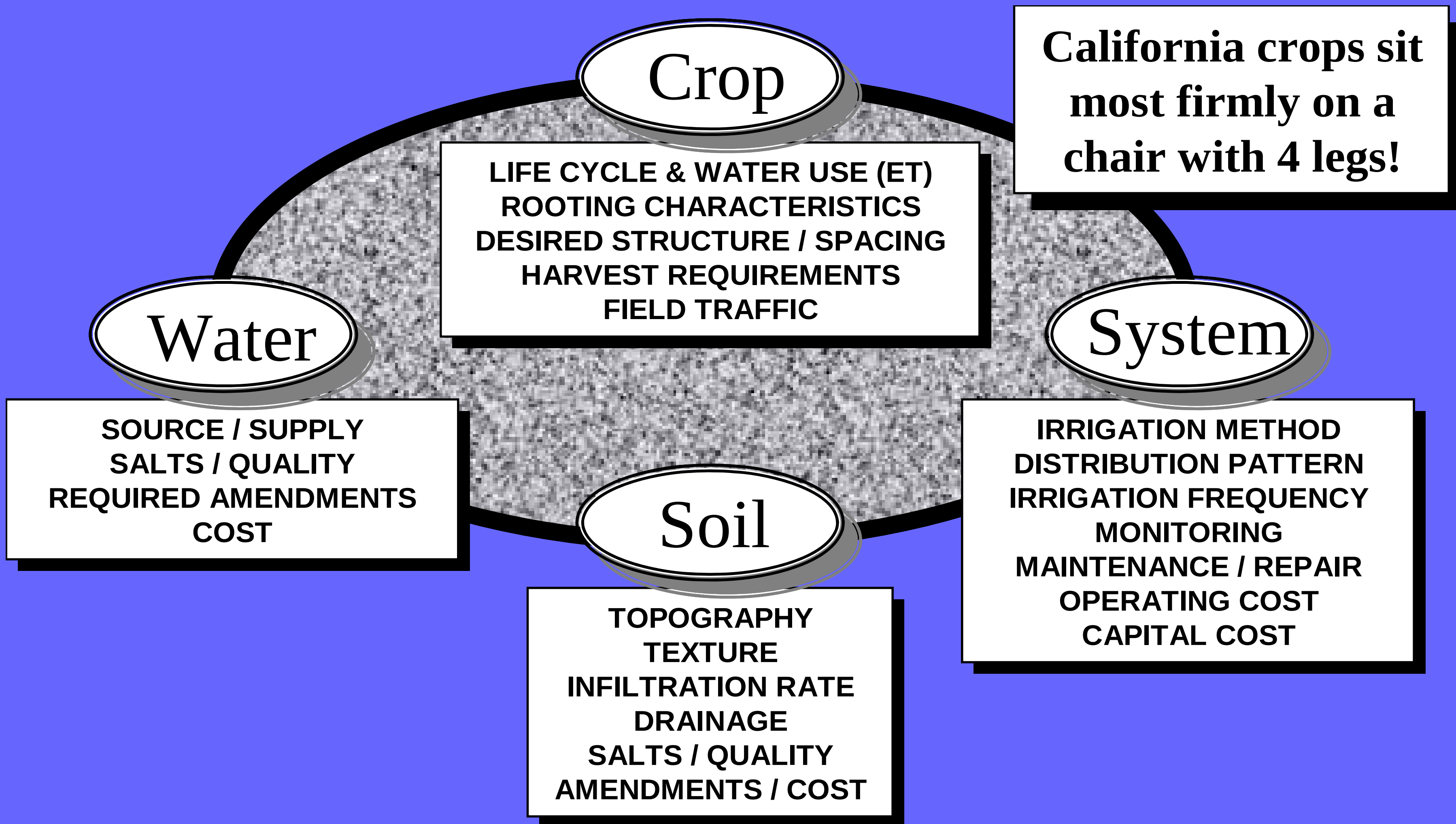
Any questions?

Creating the efficient field water balance – your soil moisture checking account!

- How big is the cup (soil AWHC)?
- How thirsty is the crop (ET)?
- How often/much do you fill the cup (Scheduling)?



The irrigation method / system is the "ESSENTIAL" integrating factor for creating an optimal water balance.

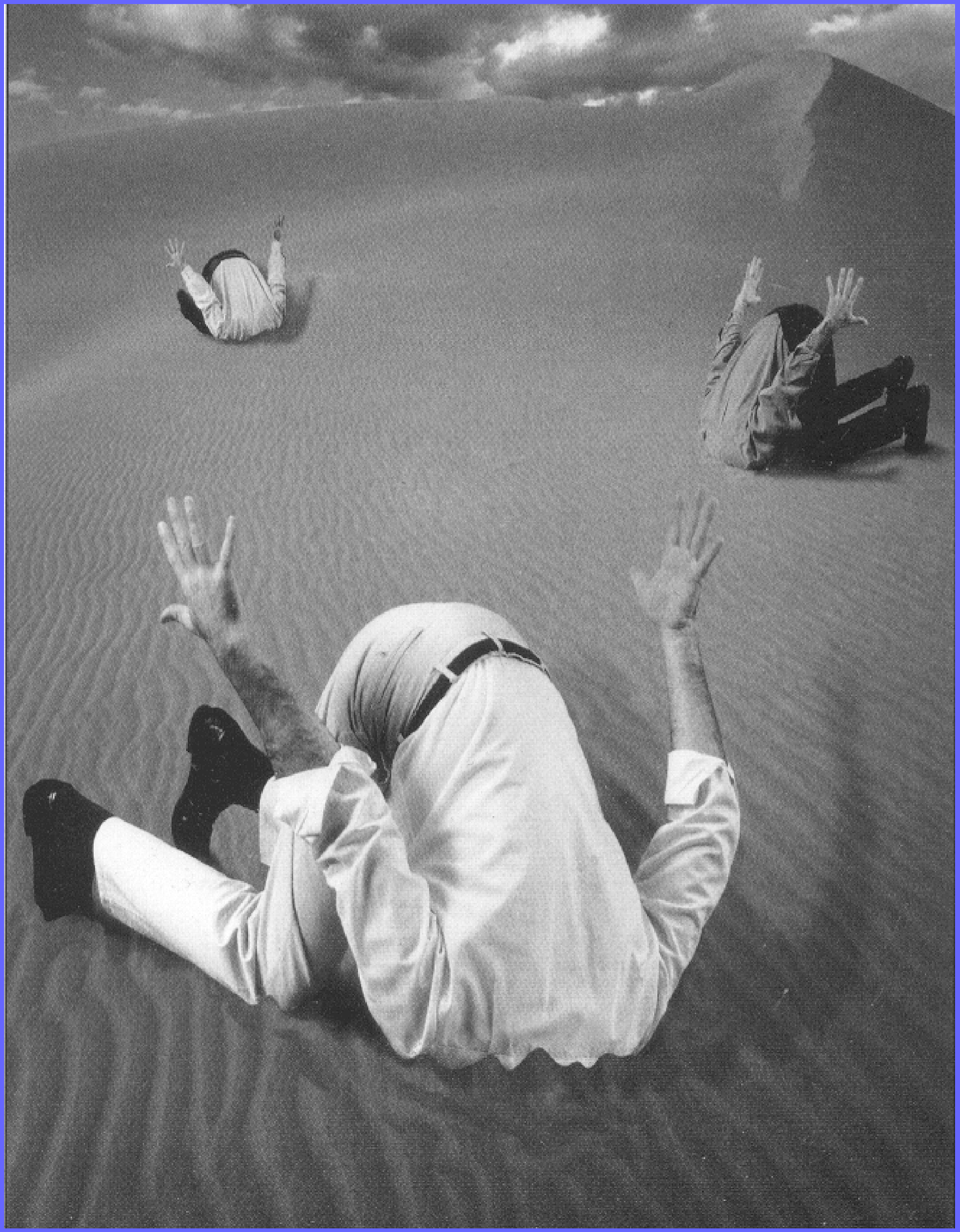


ESSENTIALS to OPTIMIZE CROP PRODUCTION

- AVAILABLE WATER
- ROOTZONE AERATION
- SUFFICIENT ROOTED VOLUME FOR ANCHORING AND NUTRIENTS
- AVAILABLE NUTRIENTS – N, P, K, Zinc, Boron, Iron
- AVOID SATURATION & HIGH HUMDITY TO DECREASE DISEASE
- CROP STRUCTURE FOR MAXIMUM PHOTOSYNTHESIS & FRUIT DEVELOPMENT
- EQUIPMENT FOR TIMELY OPERATIONS

So how do I look into the crop rootzone to optimize my field water & fertilizer budget?

There's got to be a better way!



4 3-point sermon:

- Understanding & monitoring soil water holding characteristics
- Crop water requirements (ET), CIMIS
- NPK nutrient requirements for almonds & fertigation options
- Irrigation & crop salinity tolerance

The "dirt" is the thing. Know your soil!

IDEAL: deep, well drained, non-alkali sandy to sandy clay loam

Check your dirt! It has more secrets than the CIA.

Check your dirt!

SOIL PROFILE

–SOIL TEXTURE

Analysis:

SP 48 -- saturation %

pH 7.8

EC_e 2.0 dS/m

Texture Silty Clay Loam

SOIL SURVEY

BACKHOE PITS

AUGER, PUSH PROBE

mottles, dark yellowish brown (10YR 4/6) moist; weak fine subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; many very fine and few fine roots; common very fine and few fine tubular pores and many very fine interstitial pores; neutral; clear wavy boundary.

VIIIC8—48 to 56 inches; white (10YR 8/1) silt loam, gray (10YR 5/1) moist; common medium prominent brownish yellow (10YR 6/8) mottles, dark yellowish brown (10YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; many very fine and common fine roots; many very fine and common fine tubular pores and common very fine interstitial pores; neutral; clear wavy boundary.

IXC9—56 to 65 inches; very pale brown (10YR 8/3) sand, grayish brown (10YR 5/2) moist; few fine prominent brownish yellow (10YR 6/8) mottles, dark yellowish brown (10YR 4/6) moist; single grain; loose, nonsticky and nonplastic; many very fine interstitial pores; neutral.

The soil is noneffervescent below a depth of 11 to 20 inches.

The A horizon has dry color of 10YR 5/2, 5/3, 6/2, or 6/3 and moist color of 10YR 4/2, 4/3, or 5/3. Clay content is 10 to 18 percent.

The C horizon has dry color of 10YR 6/2, 6/3, 6/6, 7/2, 7/3, 8/1, or 8/3 or 2.5Y 6/2 and moist color of 10YR 3/2, 3/3, 4/2, 4/6, 5/1, 5/2, or 5/3 or 2.5Y 4/2 or 6/2. Mottles have dry color of 10YR 5/6, 6/6, 6/8, or 8/3 or 7.5YR 5/4 and moist color of 10YR 3/6, 4/6, or 5/3 or 7.5YR 5/4. Texture is stratified sand, loamy sand, loamy fine sand, sandy loam, fine sandy loam, loam, or silt loam. Clay content is 10 to 18 percent. Reaction is slightly acid to moderately alkaline.

Exeter Series

The Exeter series consists of moderately deep, well drained soils on broad alluvial terraces. These soils formed in alluvium derived dominantly from granitic rock. Slope is 0 to 9 percent.

Soils of the Exeter series are fine-loamy, mixed, thermic Typic Durixeralfs.

Typical pedon of Exeter sandy loam, 0 to 2 percent slopes (fig. 4); on an alluvial terrace where slopes are 1 percent; about 3 miles west of Highway 65 on Highway 155, 150 feet north and 200 feet west of the southeast corner of sec. 7, T. 25 S., R. 27 E.; Richgrove Quadrangle.

Ap—0 to 4 inches; pale brown (10YR 6/3) sandy loam, dark brown (10YR 3/3) moist; weak very coarse platy structure; very hard, friable, nonsticky and nonplastic; common very fine roots; many very fine interstitial pores and few very fine tubular pores; neutral; clear smooth boundary.

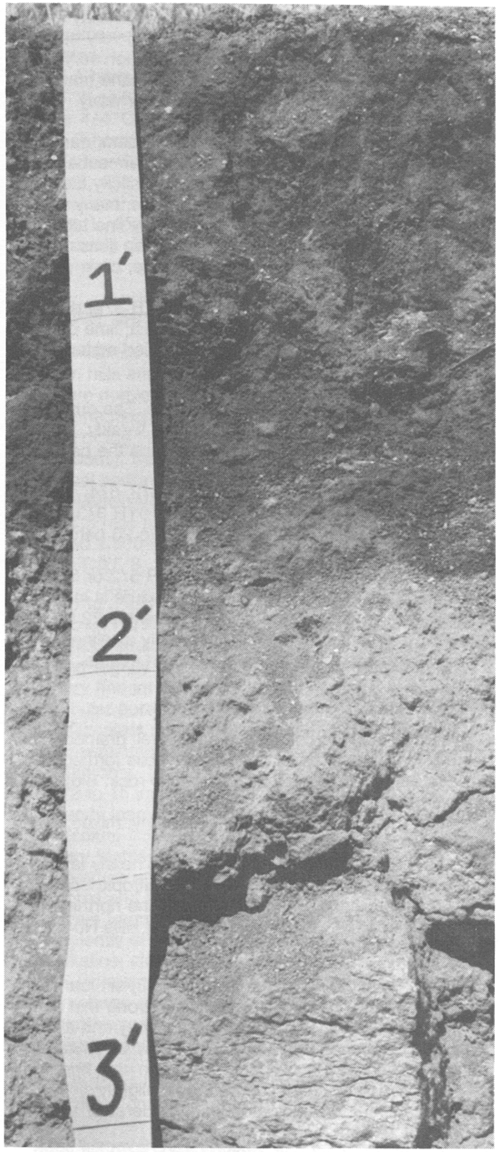


Figure 4.—Profile of Exeter sandy loam, 0 to 2 percent slopes. A duripan is at a depth of about 24 inches.

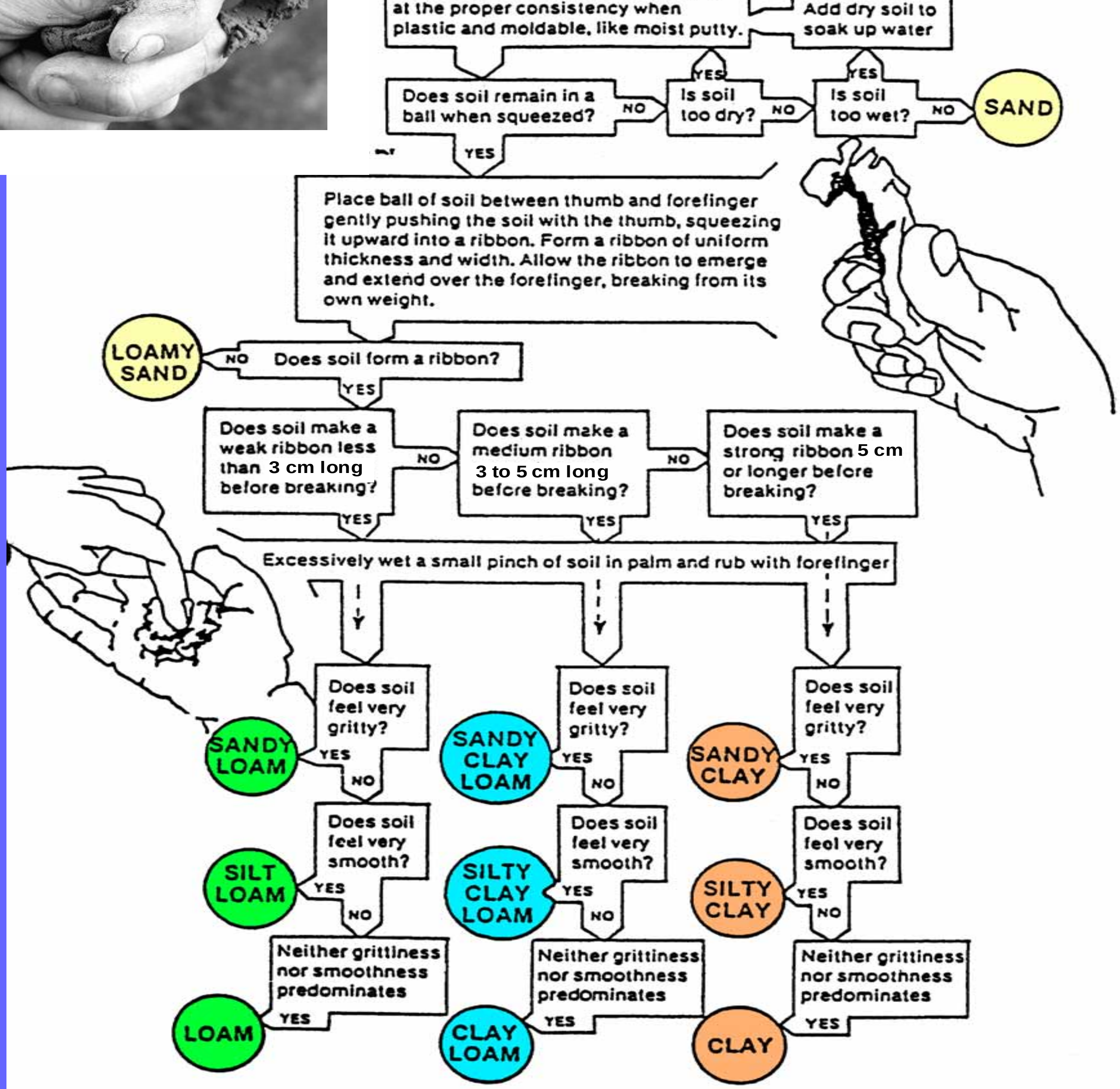
Backhoe Pits – the Worm's Eye View!

SOIL TEXTURE DETERMINES AVAILABLE WATER HOLDING CAPACITY

SOIL TEXTURE
“FEEL METHOD”

$$\text{AWHC} = \%\text{Volume} = \frac{\text{inch depth of water}}{\text{1 foot depth of soil}}$$

SOIL TEXTURE "FEEL METHOD" FLOWCHART



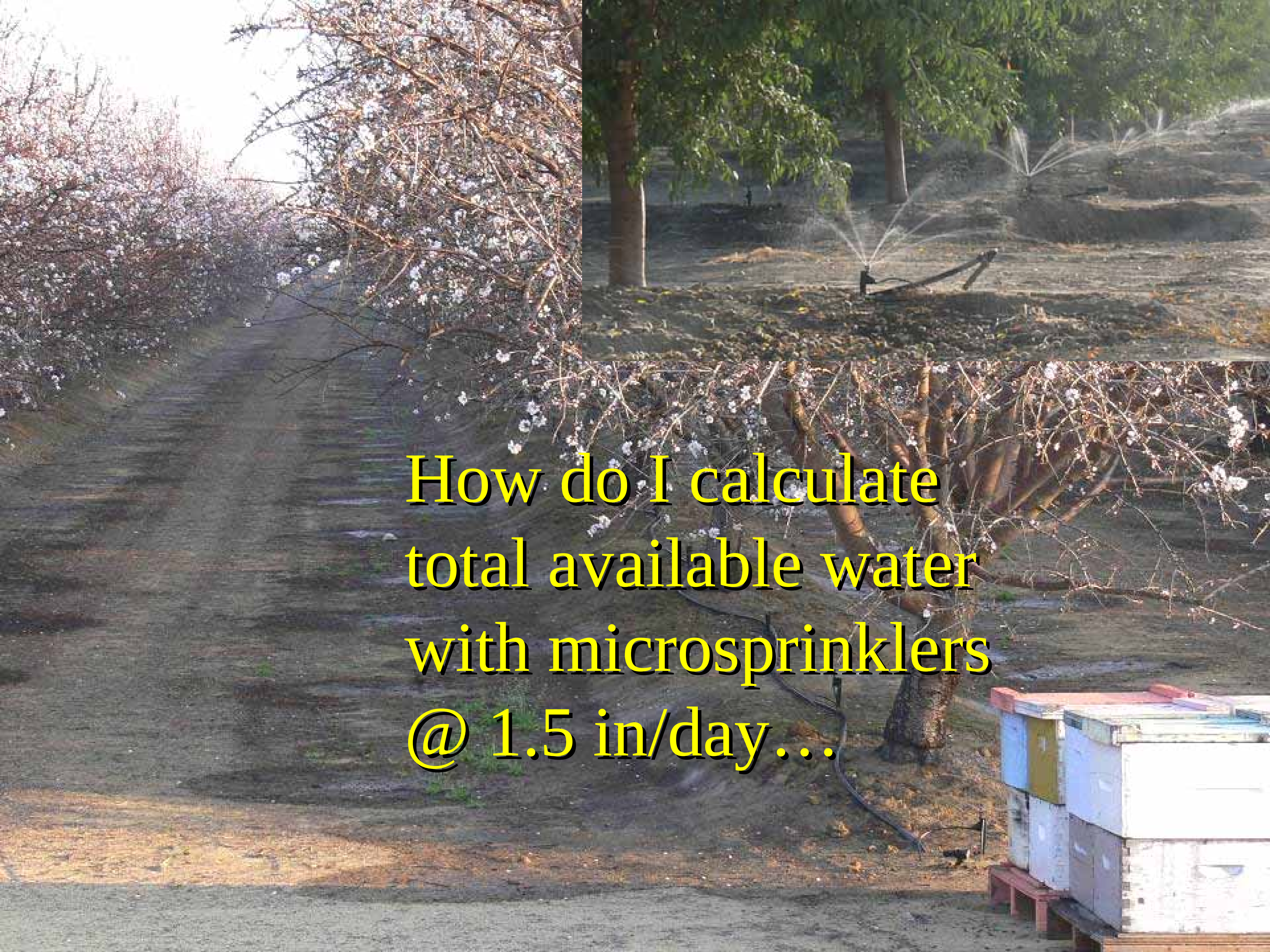
The “dirt” is the thing. Know your soil!

Soil Texture	Field Capacity (in/ft)	Wilting Point (in/ft)	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	*Moisture Reserve (gals)
Sand	1.2	0.5	0.7	2	4
Loamy Sand	1.9	0.8	1.1	3	16
Sandy Loam	2.5	1.1	1.4	4	35
Loam	3.2	1.4	1.8	5	70
Silt Loam	3.6	1.8	1.8	6	102
Sandy Clay Loam	3.5	2.2	1.3	7	100
Sandy Clay	3.4	1.8	1.6	7	123
Clay Loam	3.8	2.2	1.7	8	170
Silty Clay Loam	4.3	2.4	1.9	9	241
Silty Clay	4.8	2.4	2.4	9	305
Clay	4.8	2.6	2.2	10	345

*This is the maximum gallons of water stored to a 4' depth beneath a single drip emitter. In fine textured soils, the wetted volume of one emitter merges with another on the same hose and final gallons of moisture reserve per emitter will be less than the number shown in the table. Plant stress will usually be seen when about 50% of this reserve has been used.

Ref: Ratliff LF, Ritchie JT, Cassel DK. 1983. Field-measured limits of soil water availability as related to laboratory-measured properties. Soil Sci Soc Am. 47:770-5.


What about wetting patterns?
18 inch valves @ 2000
gpm = 4 in/4 hr


How do I calculate
total available water
with microsprinklers
@ 1.5 in/day…


… or account for "subbing" in a double-line drip?

Estimating Water Holding Capacity & Microirrigation Set Times for Orchards

Refill Times for Different Soil Textures and Micro Systems

[1]Irrigation Time to Refill & Moisture Reserve of 4 Foot Wetted Rootzone @ 50% to 100% Available

ALMONDS 0.28 inch/day ET

Soil Texture	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	Dble-Line Drip 1-gph, 10 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	10 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	14 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)
Sand	0.7	2	2.2	0.3	11.6	1.6	12.5	2.4
Loamy Sand	1.1	3	7.8	1.0	19.6	2.7	20.9	4.0
Sandy Loam	1.4	4	17.5	2.4	26.9	3.6	28.3	5.4
Loam	1.8	5	35.9	4.9	37.1	5.0	38.6	7.3
Silt Loam	1.8	6	43.1	5.8	39.7	5.4	40.8	7.7
Sandy Clay Loam	1.3	6	31.1	4.2	28.6	3.9	29.5	5.6
Sandy Clay	1.6	7	44.7	6.0	37.6	5.1	38.3	7.2
Clay Loam	1.7	8	54.3	7.3	42.6	5.8	42.9	8.1
Silty Clay Loam	1.9	9	68.2	9.2	50.6	6.8	50.5	9.6
Silty Clay	2.4	9	86.2	11.6	64.0	8.6	63.8	12.1
Clay	2.2	10	87.8	11.9	62.3	8.4	61.5	11.6

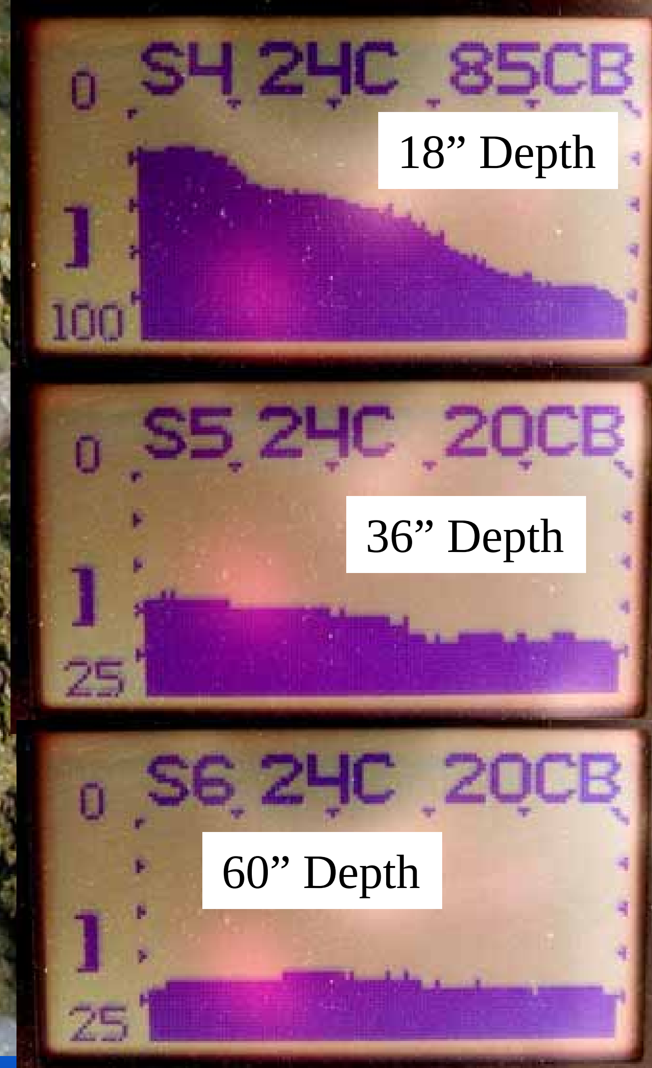
[1]Based on a tree spacing of 20 x 22'. Drip hoses 6' apart. 10 gph fanjet wets 12' diameter. 14 gph fanjet @ 15' diameter

Note: Peak water use @ 0.28"/day and 20 x 22' spacing = 74 gallons/day/tree. 0.20"/day = 55 gallons/day/tree.

Table takes into account merging water patterns below soil surface for drip irrigation.

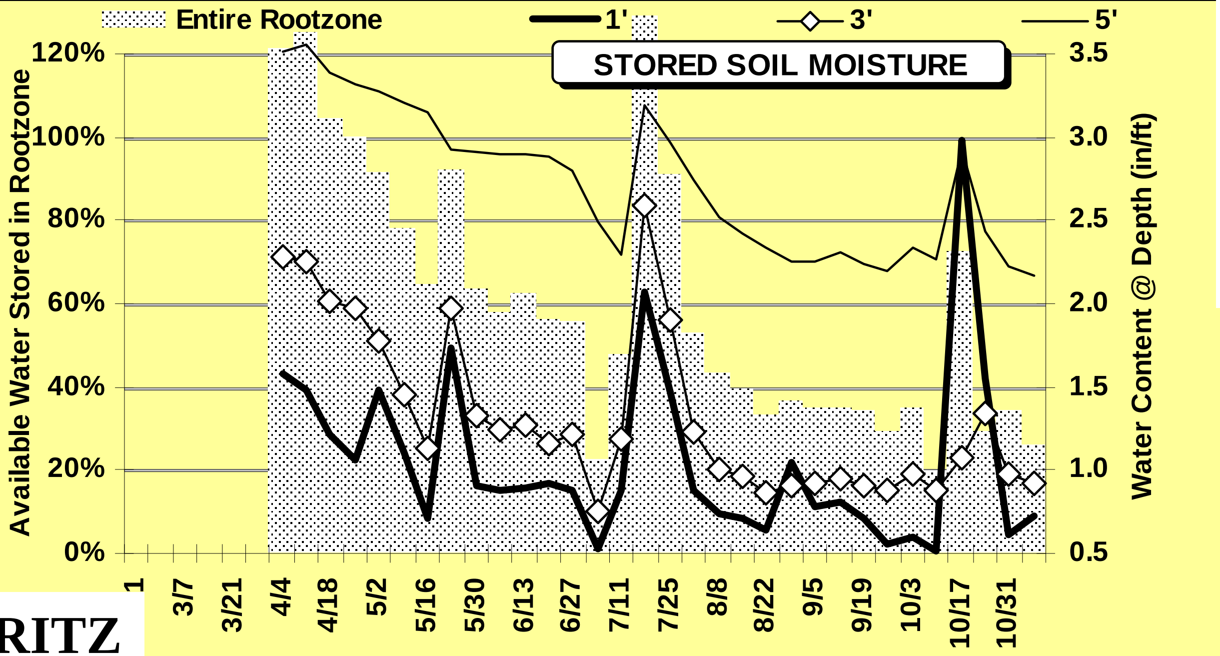
3 foot push or slide hammer-type probe.

Hand-powered twist augers



Checking reliability of dry readings on tensiometers with a soil core obtained with a 3 foot hammer probe.

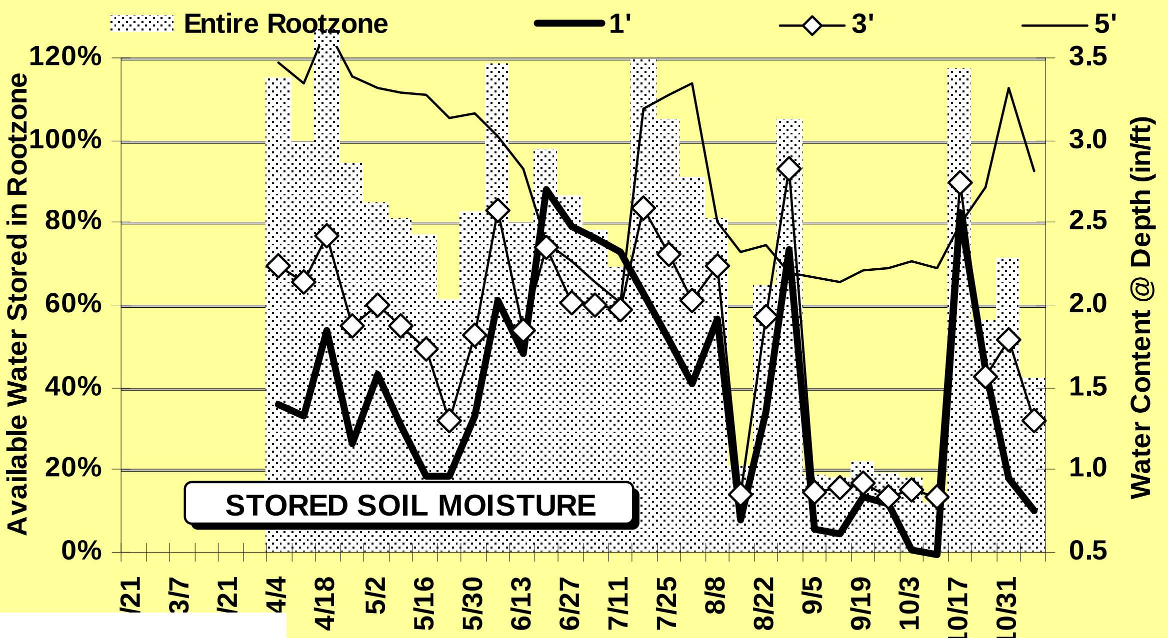
A device using low levels of radiation, the neutron probe, was developed in the 1960's for checking soil moisture. Used mostly by researchers and irrigation consultants, it is often the standard check for the accuracy of other instruments. Largest sample "volume" to estimate moisture.



FRITZ

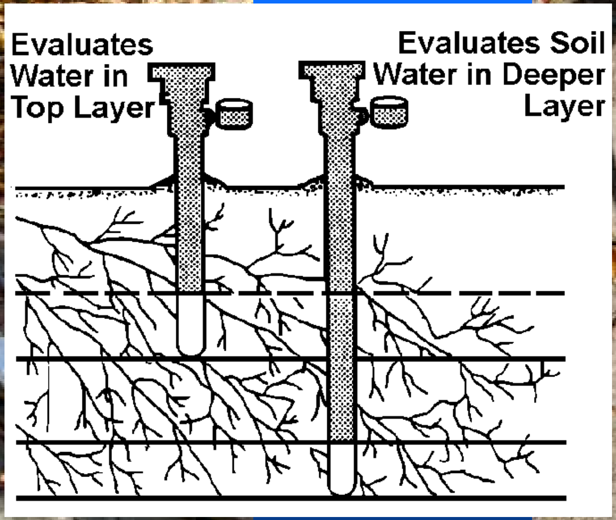
Neutron probe water content profile for 7th leaf Fritz on fanjet, 3500 lb/ac yield and 44.8 inches irrigation. Average available water = 60%

"Normal Year" ET is just a guide. Check soil moisture to prevent defoliation and insure sustained yields



NONPARIEL

Neutron probe water content profile for Nonpariel in adjacent row, 3000 lb/ac yield and 44.8 inches irrigation. Average available water = 73%

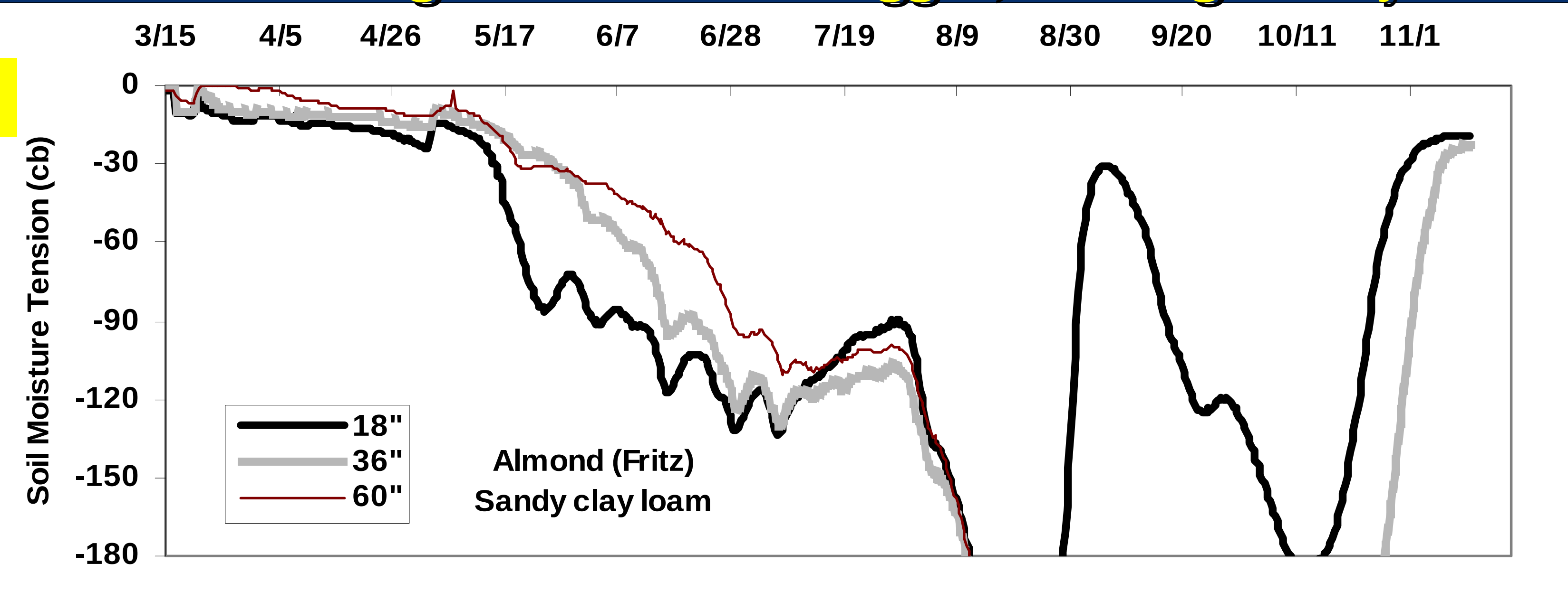


Tensiometers, Watermarks for Soil Moisture Tension (matric potential)

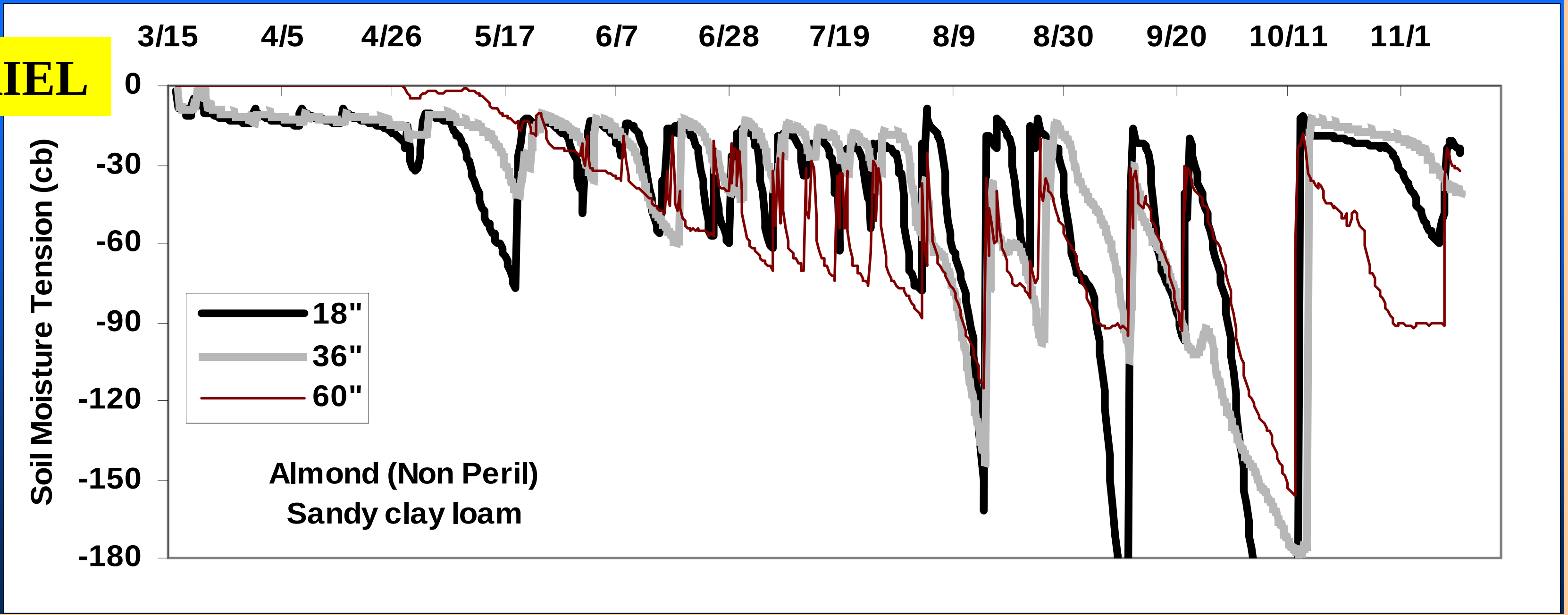
A variety of loggers can be used for various sensors: Costs from $100 (Hobo) to $5,000 (Campbell)

Watermark Readings from AM400 logger, reading 3x/day

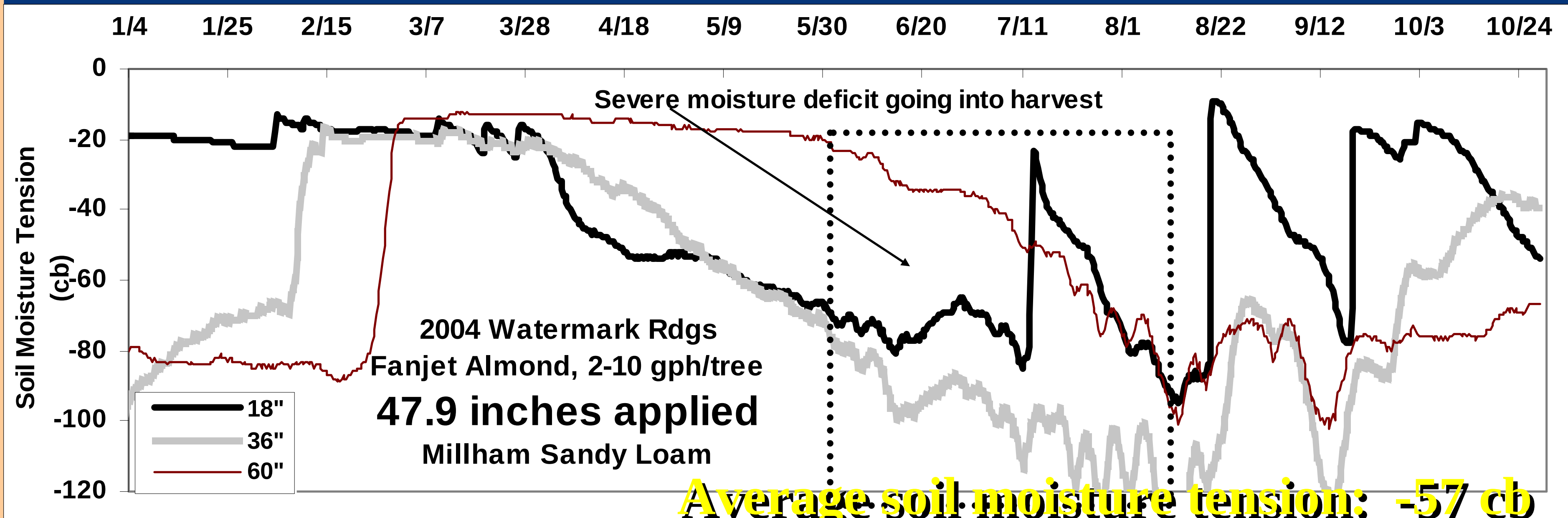
FRITZ

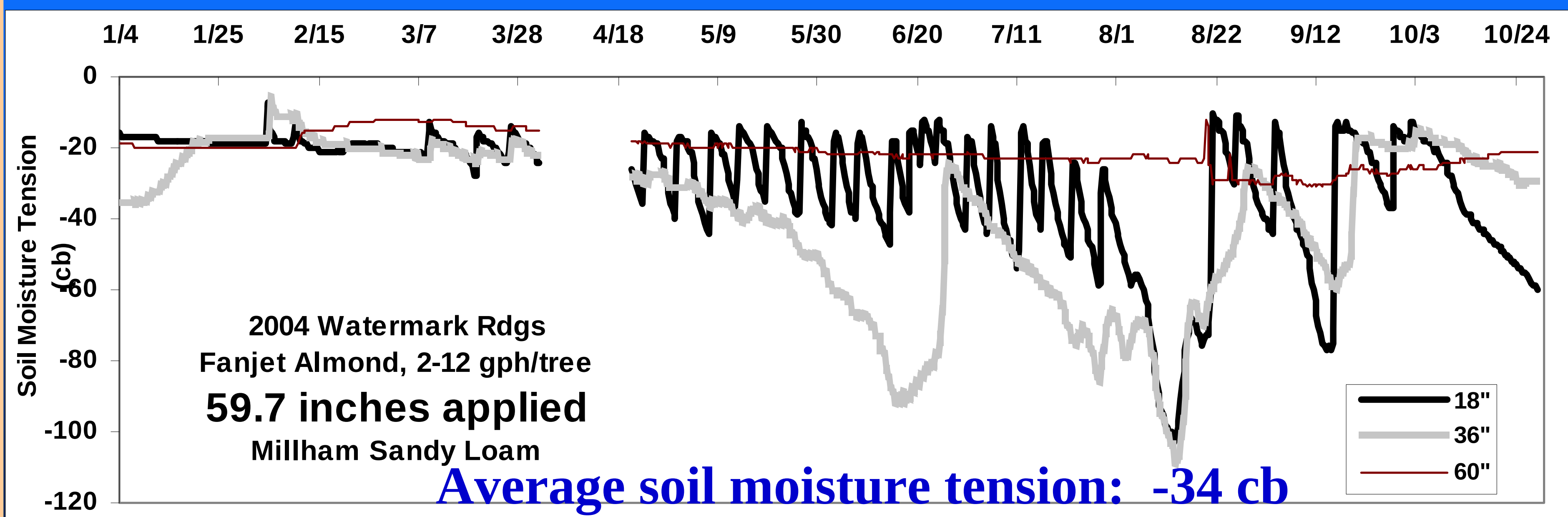


NONPARIEL

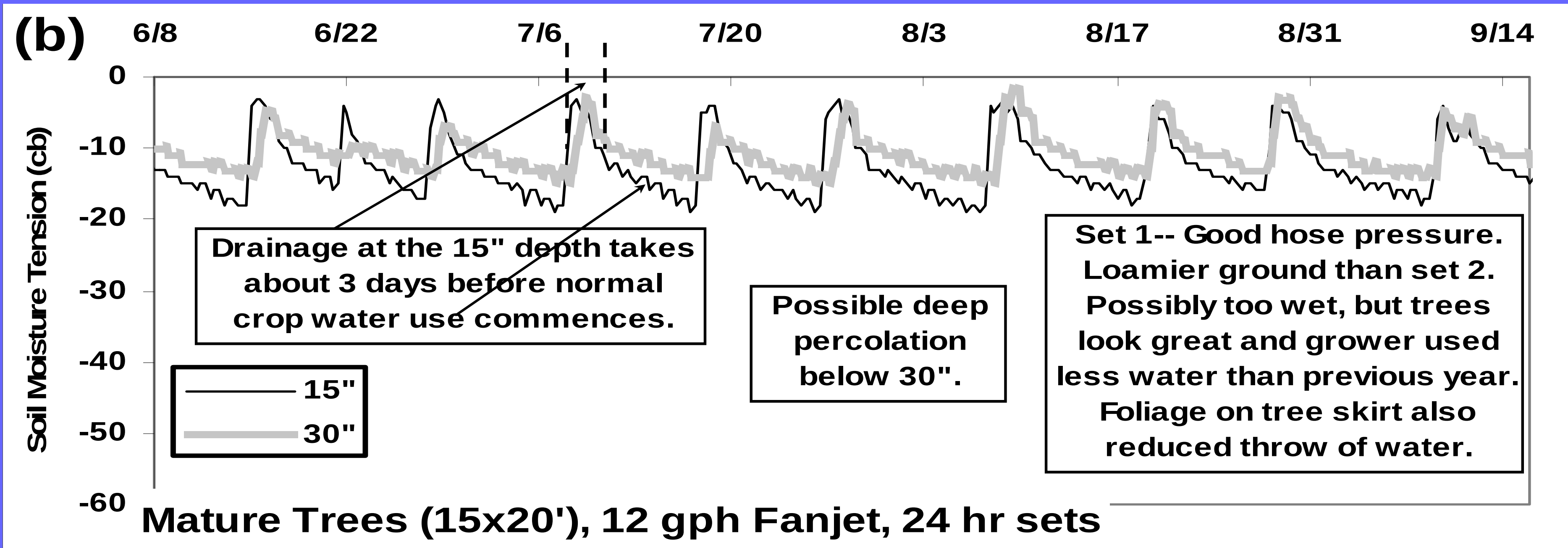


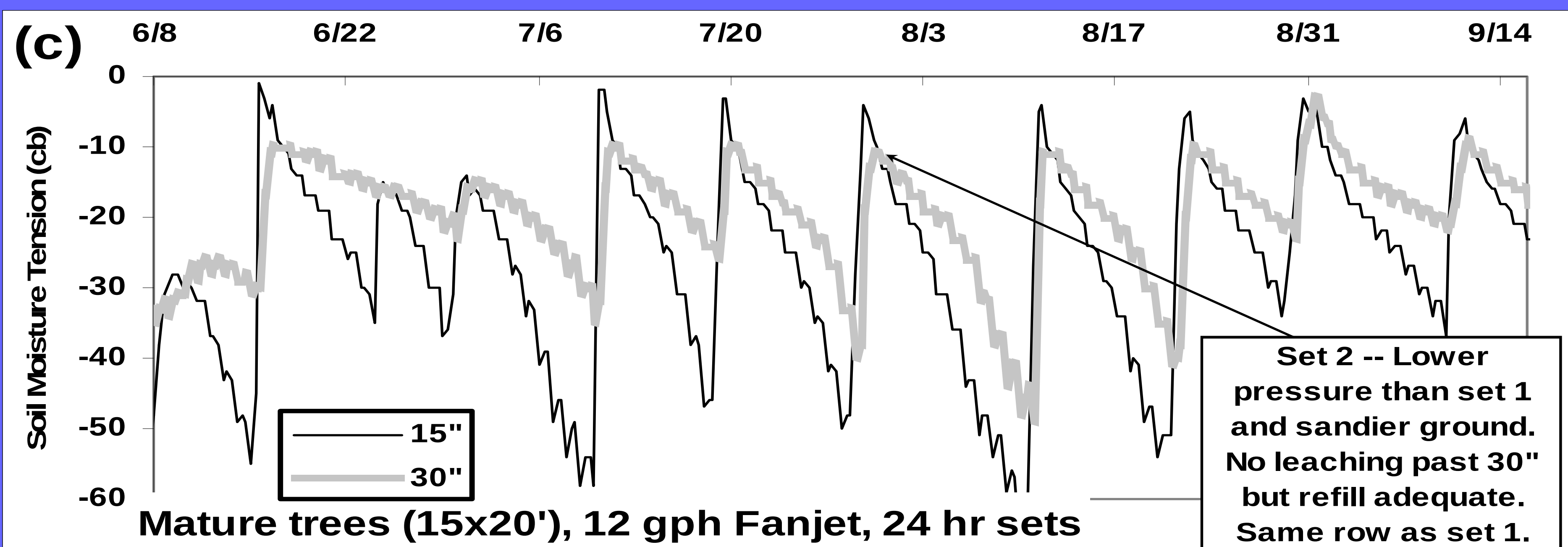
Watermark Readings from AM400 logger, reading 3x/day





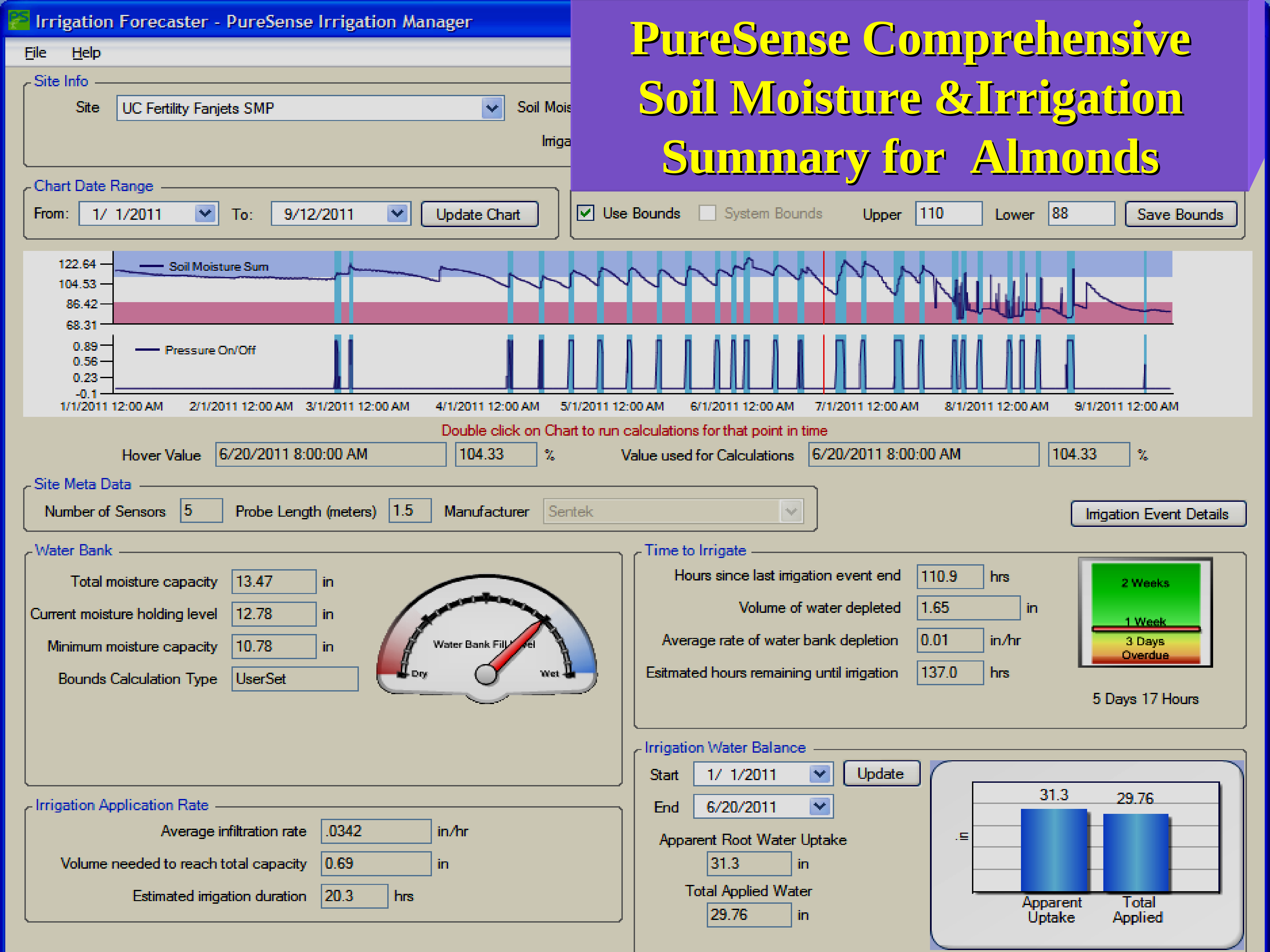
Soil Moisture Changes in Citrus Under Different Manifold Pressures



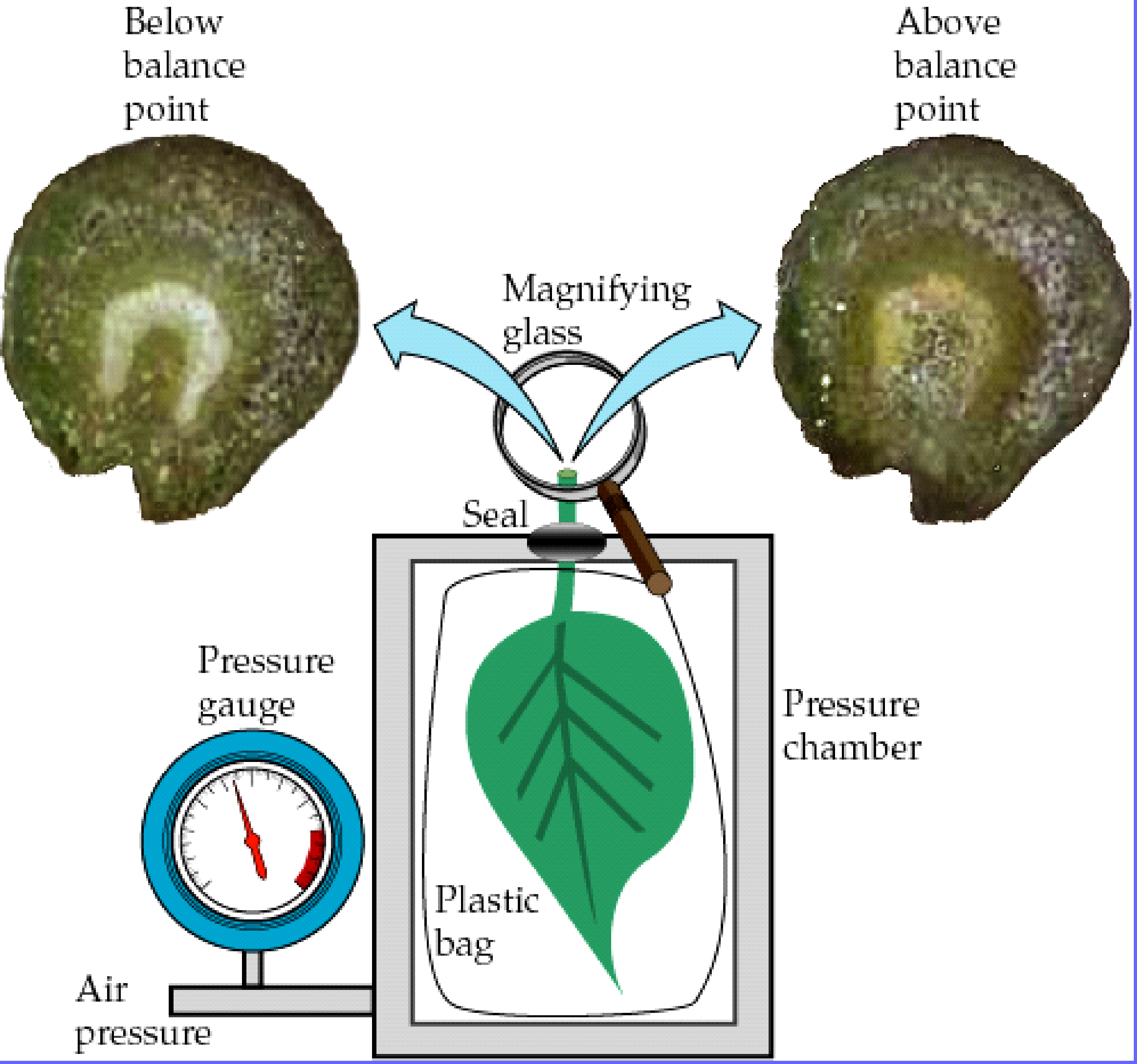


Electronics, data loggers, weather stations and multi-stage sensors can increase the cost rapidly up to $5,000 to $10,000. Does this degree of sophistication payoff?

PureSense Comprehensive Soil Moisture &Irrigation Summary for Almonds

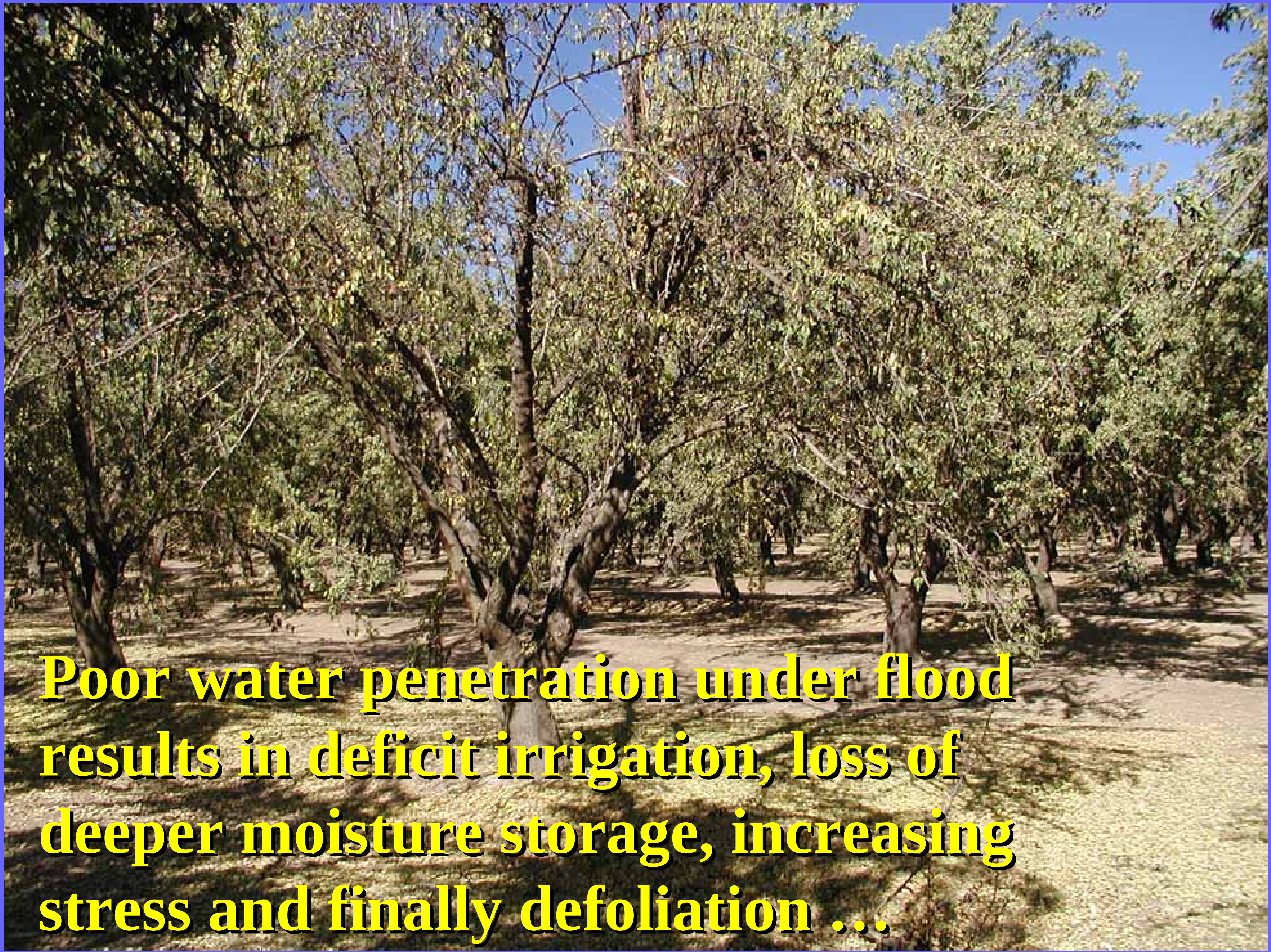


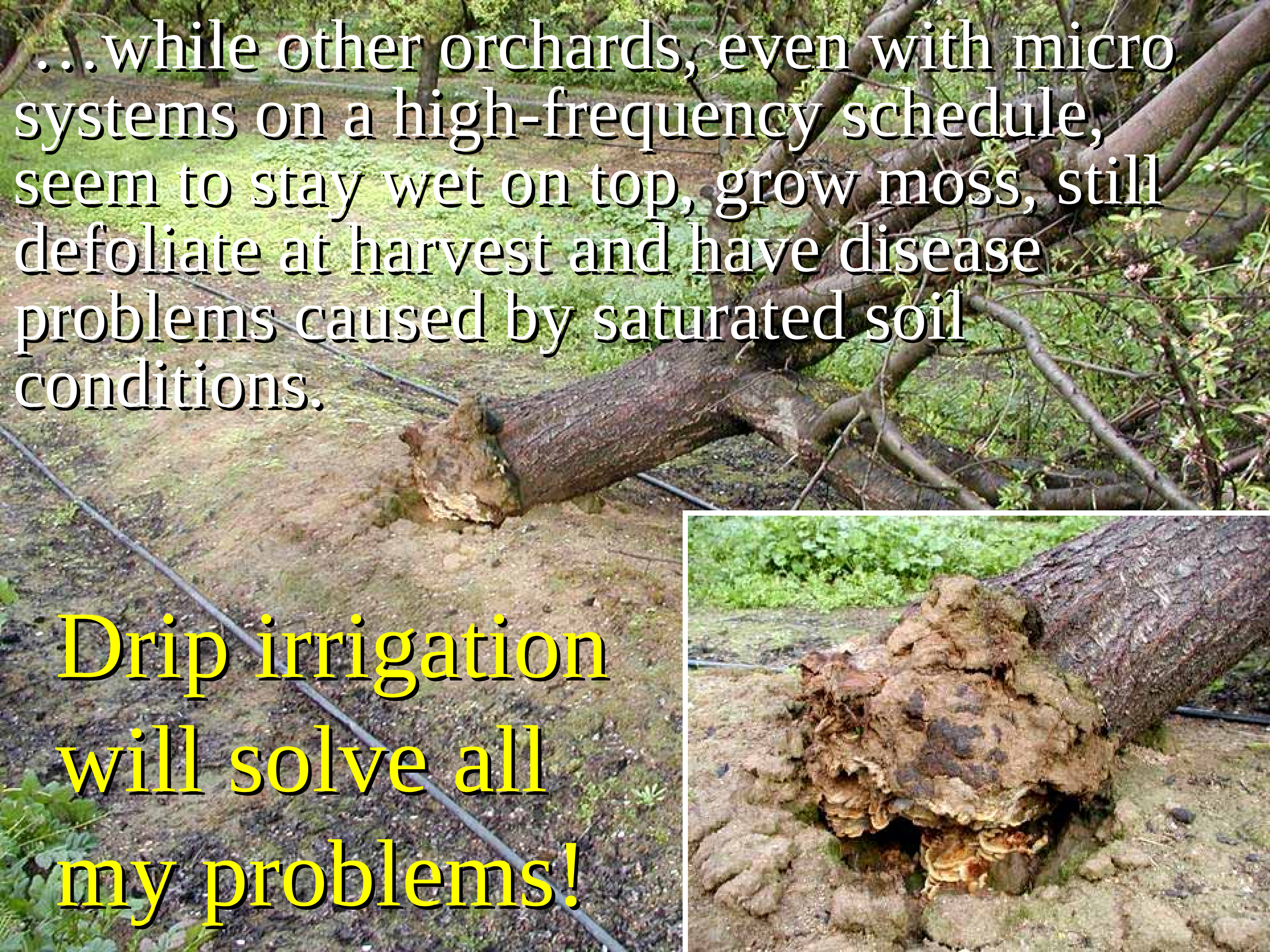
Use the pressure bomb to check Stem Water Potential (SWP) to determine when to start your first spring water in flood blocks where water penetration is not a problem.



Pressure applied to the leaf forces liquid out of the xylem.

(Diagram courtesy of Ken Shackel)


Poor water penetration under flood results in deficit irrigation, loss of deeper moisture storage, increasing stress and finally defoliation …


…while other orchards, even with micro systems on a high-frequency schedule, seem to stay wet on top, grow moss, still defoliate at harvest and have disease problems caused by saturated soil conditions.
Drip irrigation will solve all my problems!

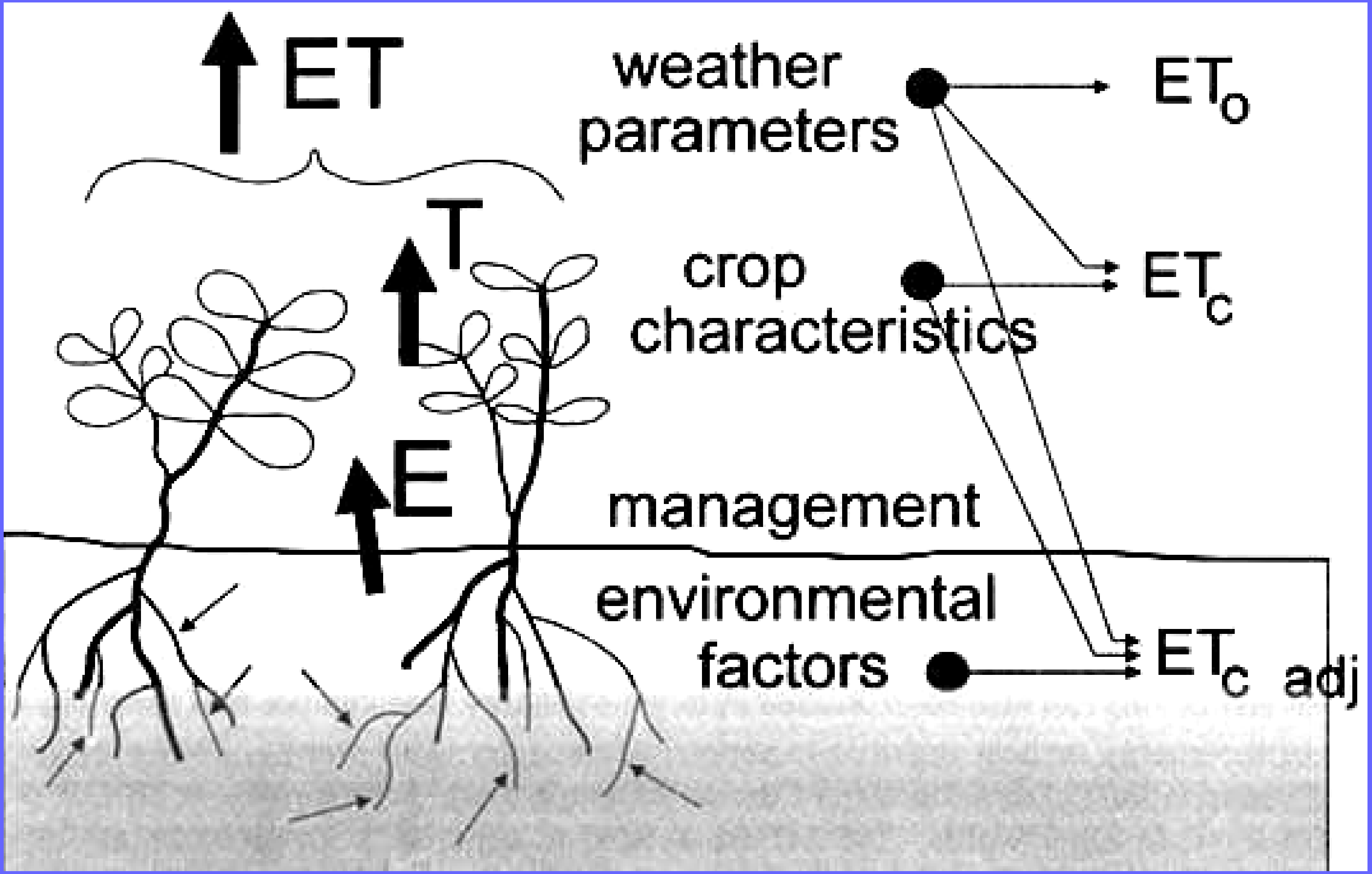
Equipment for checking soil Moisture

- Seat of the pants still most common method

~~4~~ 3-point sermon:

- Understanding & monitoring soil water holding characteristics
- Crop water requirements (ET), CIMIS
- NPK nutrient requirements for almonds & fertigation
- ~~Irrigation & crop salinity tolerance~~

Crop water use is made up of EVAPORATION (E) from the wet soil and leaves and TRANSPIRATION (T), hence ET



Blake with his first soil probe checking alfalfa

We haven’t been out of the cave that long regarding a scientific understanding of crop water use and “Normal Year” ET

From 1968 to 1990 detailed records of Class A pan evaporation were recorded in dozens of locations around the SJV.

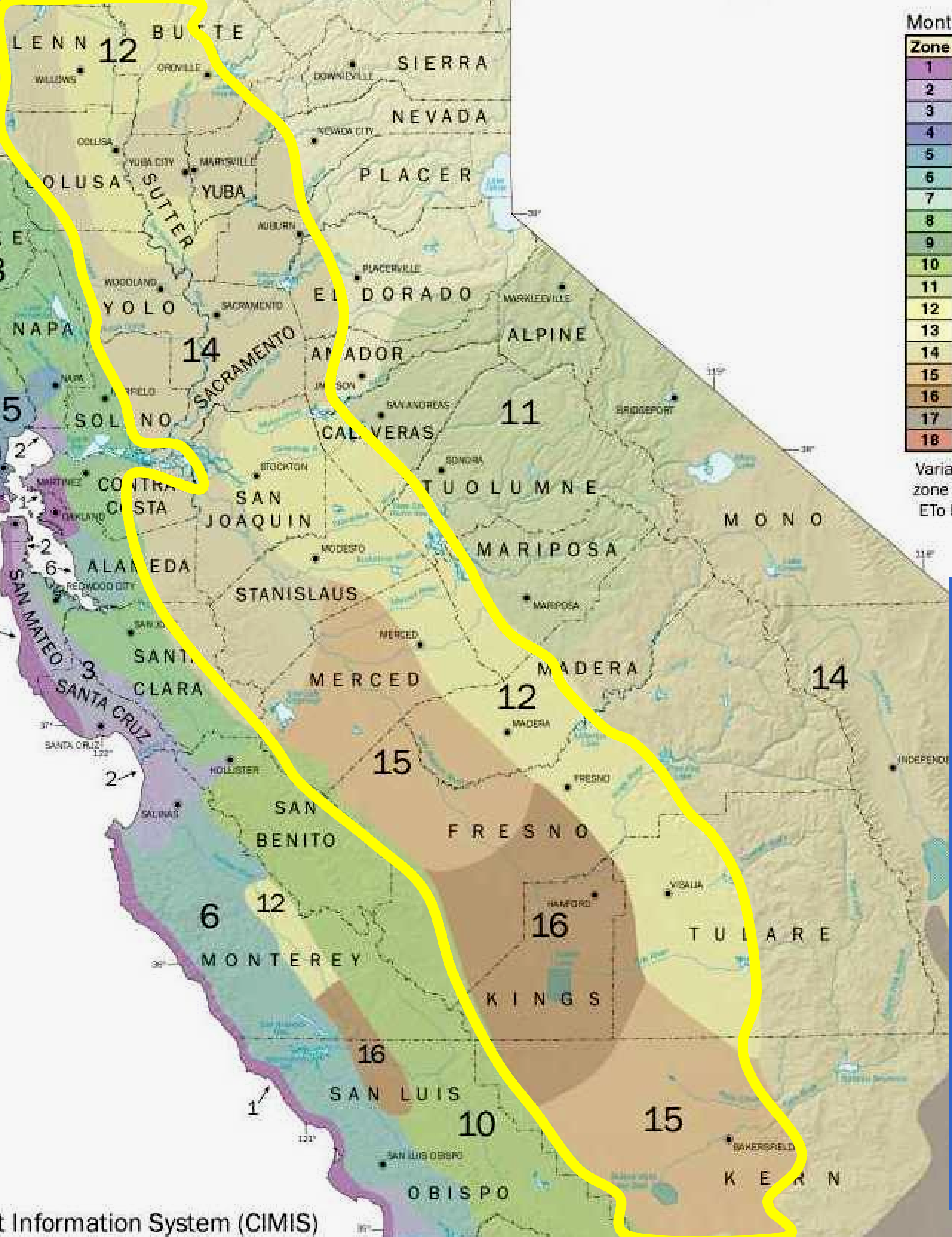
Using ETo = 0.85 Evaporation

a **20 year average ETo of 49.3 inches** was published by CA Dept of Water Resources

CIMIS

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SERVICE

Courtesy of Mark Anderson, DWR



Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

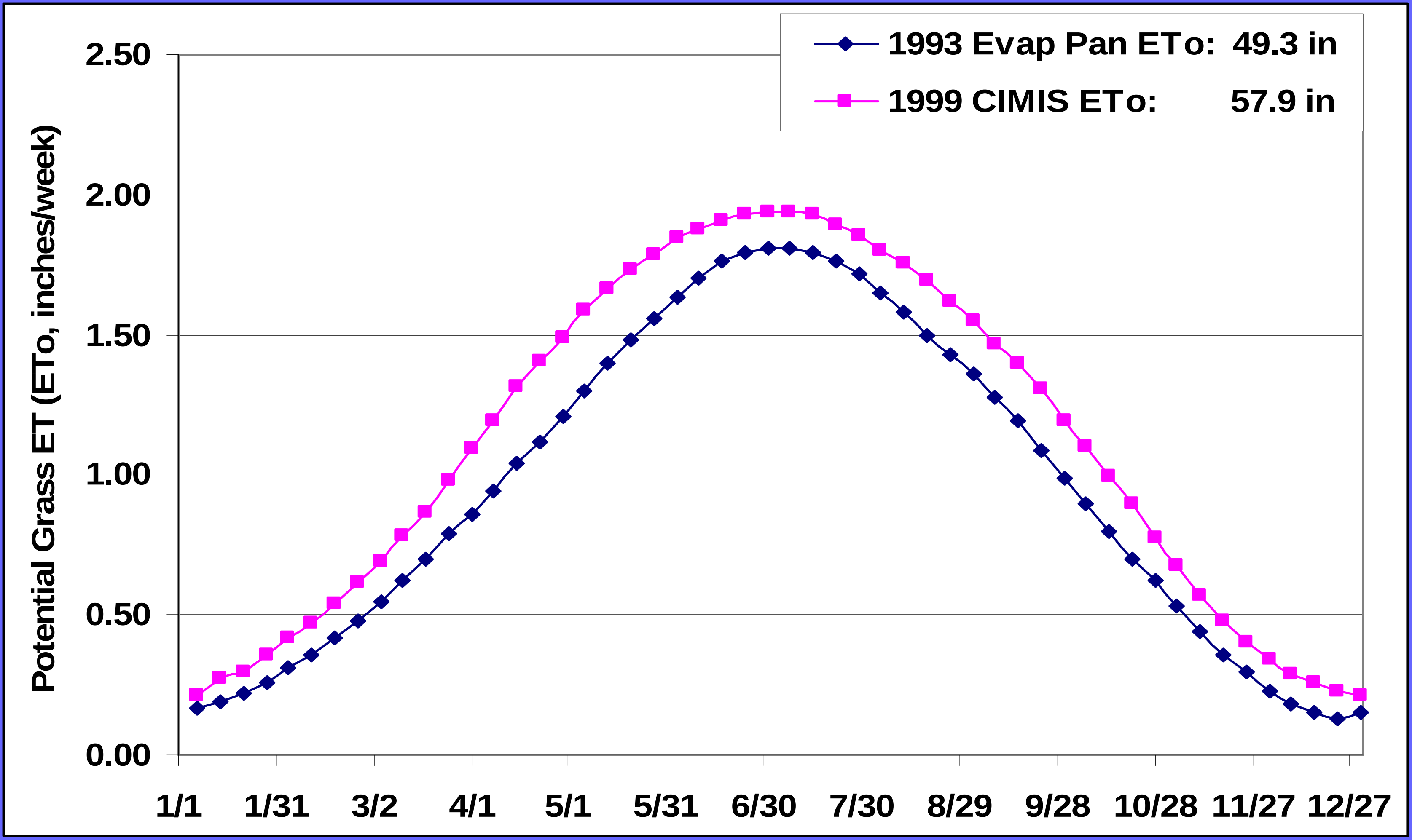
Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	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

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

The whole Central Valley covers Zones 12 to 16: for an "normal year" ETo of 53.3 to 62.5 in/yr, with most area @ 53 to 58 inches.

Comparing 1993 and 1999 estimates of Potential Evapotranspiration (ETo) for SJV

(Potential ETo, reference crop ET, is water use by a tall cool-season non-stressed pasture grass)



Calculating ET for crops:

$$ET_{crop} = ET_o * K_c * E_f$$

ET_o = **reference crop** (tall grass) ET

K_c = **crop coefficient** for a given stage of growth as a ratio of grass water use. May be 0 to 1.3, standard values are good starting point.

E_f = an "**environmental factor**" that can account for immature permanent crops and/or impact of salinity. May be 0.1 to 1.1, determined by site.

CIMIS ET Estimates Using Zone 15 Southern SJV "Historic" ETo								
	Normal Year Grass ETo (in)	Mature Crop Coef-ficient (Kc)	Almond ET -- Minimal Cover Crop, MIcrosprinkler (S. San Joaquin Valley)					20X22 Spacing Gallon / day / tree
Week			1st Leaf @ 40%	2nd Leaf @ 55%	3rd Leaf @ 75%	4th Leaf @ 90%	Mature	
1/6	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**	**3**
1/13	0.28	0.40	0.03	0.06	0.08	0.10	**0.11**	**4**
1/20	0.30	0.40	0.04	0.07	0.09	0.11	**0.12**	**5**
1/27	0.36	0.40	0.04	0.08	0.11	0.13	**0.14**	**6**
2/3	0.42	0.40	0.05	0.09	0.13	0.15	**0.17**	**7**
2/10	0.47	0.40	0.06	0.10	0.14	0.17	**0.19**	**7**
2/17	0.54	0.40	0.06	0.12	0.16	0.19	**0.22**	**8**
2/24	0.61	0.40	0.07	0.13	0.18	0.22	**0.24**	**10**
6/9	1.86	0.99	0.55	1.01	1.38	1.65	**1.83**	**72**
6/16	1.90	1.02	0.58	1.06	1.45	1.74	**1.93**	**76**
6/23	1.93	1.05	0.61	1.11	1.52	1.82	**2.03**	**79**
6/30	1.93	1.06	0.62	1.13	1.54	1.85	**2.05**	**80**
7/7	1.93	1.08	0.62	1.14	1.56	1.87	**2.07**	**81**
7/14	1.93	1.08	0.62	1.14	1.56	1.87	**2.07**	**81**
7/21	1.86	1.08	0.60	1.10	1.50	1.80	**2.00**	**78**
7/28	1.86	1.07	0.60	1.10	1.50	1.79	**1.99**	**78**
8/4	1.78	1.07	0.57	1.05	1.44	1.72	**1.91**	**75**
8/11	1.75	1.08	0.57	1.04	1.42	1.70	**1.89**	**74**
8/18	1.69	1.08	0.55	1.00	1.36	1.64	**1.82**	**71**
8/25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10/27	0.77	0.83	0.19	0.35	0.48	0.58	**0.64**	**25**
11/3	0.67	0.78	0.16	0.29	0.39	0.47	**0.53**	**21**
11/10	0.57	0.71	0.12	0.22	0.31	0.37	**0.41**	**16**
11/17	0.48	0.68	0.10	0.18	0.25	0.30	**0.33**	**13**
11/24	0.42	0.60	0.07	0.14	0.19	0.22	**0.25**	**10**
12/1	0.36	0.50	0.05	0.10	0.13	0.16	**0.18**	**7**
12/8	0.31	0.40	0.04	0.07	0.09	0.11	**0.12**	**5**
12/15	0.29	0.40	0.03	0.06	0.09	0.10	**0.11**	**4**
12/22	0.25	0.40	0.03	0.06	0.08	0.09	**0.10**	**4**
12/29	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**	**3**
Total	**57.90**		**15.68**	**28.75**	**39.20**	**47.05**	**52.27**	

Remember Regulated Deficit Irrigation (RDI)?

"Ideal RDI is planned water deficits at specific crop developmental stages that control vegetative growth without negatively affecting production.

Goals: Solve horticultural problems;
Reduce water use;
Achieve higher farm profits."

(Dave Goldhamer, 2007)

1992-1996 Kern County RDI trial: 10 different treatments (Goldhamer & Viveros)

Table 1. Simplified average results of 5 year regulated deficit irrigation (RDI) trial in almonds.

ET Treat-ment	Irrigation (inch)	Kernal Weight (g)	Yield (lb/ac)	*Predawn LWP July (bars)	*Predawn LWP August (bars)
55%	22.8	1.13	1503	-17	-24
75%	28.3	1.17	1639	-11	-22
85%	33.8	1.24	1722	-10	-23
100%	42.1	1.30	1870	-6	-15

*Approximate average of treatment leaf water potential for the month as measured within 1 hour of dawn.

2 significant findings from RDI trials:

1. August/Post-harvest irrigation critical to following year nut load
2. Hull rot was reduced and hull split was advanced by applying only 50% of normal irrigation for June and first half of July. (100 lb/ac yield loss, statistically insignificant.)

Westside Almond Irrigation & N trial – Yields, applied water, & 2003 soil moisture.

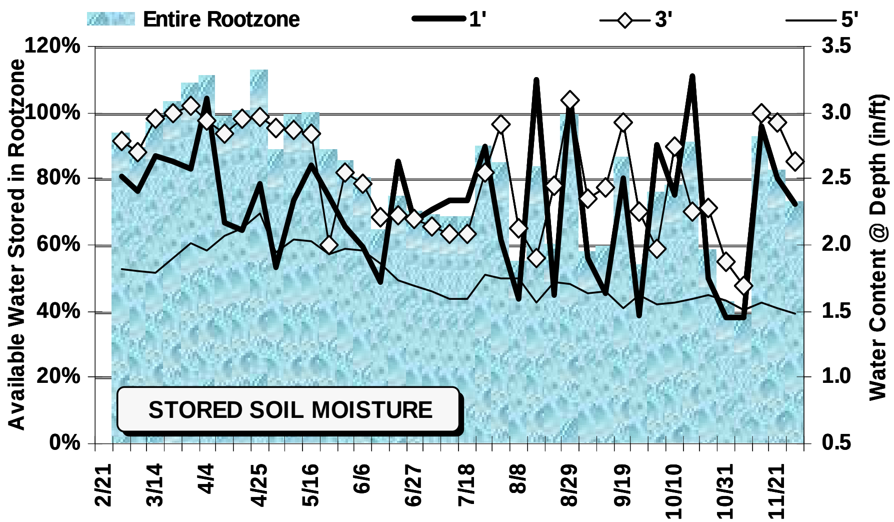
Nonpariel yields (lb/ac) by applied irrigation & N fertilizer (lb/ac) (starting year 5th leaf, NW Kern)

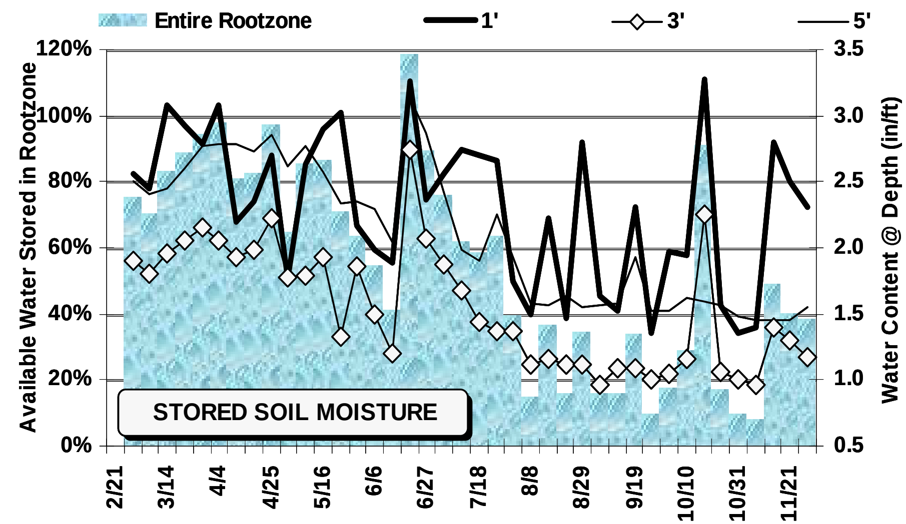
	Full Irrigation (in)	N~250	N~125	Reduced Irrigation (in)	N~250	N~125
2001	?	1926	1898	(-25%)	1979	1992
2002	48.5	1922	1275	38.8	1593	1215
2003	57.6	3004	2030	47.1	2352	1901
2004	59.7	2838	2752	47.9	2307	2209
2005	53.8	2227	1493	44.5	1758	1538
2006	52.5	3241	2697	41.5	2739	2330
2002-6	**272.1**	**13232**	**10247**	**219.8**	**10749**	**9193**
Wtr Use Eff (lb/in)		**48.6**	**37.7**		**48.9**	**41.8**

Lampinen, B., T.Dejong, S.Weinbaum, S.Metcalf, C. Negron, M.Viveros, J. McIlvane, N.Ravid, and R.Baker. 2007. Spur dynamics and almond productivity. CA Almond Board 2006 Conference Proceedings, 18pp.

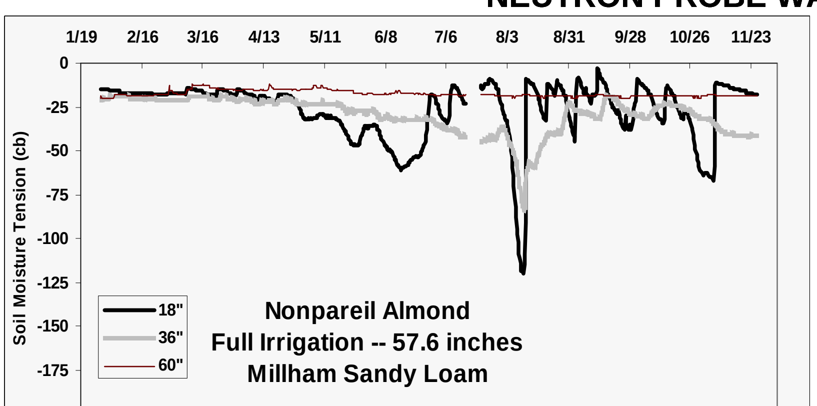
Full Irrigation
57.6 Total for 2003
3.2” Dormant Refill
54.4” In-Season

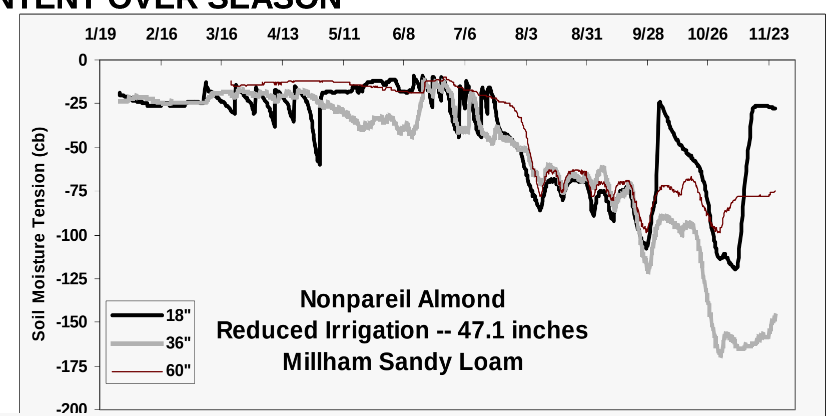
Reduced Irrigation
47.9 Total for 2003
2.9” Dormant Refill
45.0” In-Season





NEUTRON PROBE WATER CONTENT OVER SEASON





WATERMARK® SOIL MOISTURE TENSION OVER SEASON

Nonpariel yields (lb/ac) by applied irrigation & N fertilizer (lb/ac) (starting year 5th leaf, NW Kern)

	Full Irrigation			Reduced Irrigation		
	(in)	**N~250**	**N~125**	**(in)**	**N~250**	**N~125**
2001	?	1926	1898	(-25%)	1979	1992
2002	48.5	1922	1275	38.8	1593	1215
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Wtr Use Eff (lb/in)		**48.6**	**37.7**		**48.9**	**41.8**

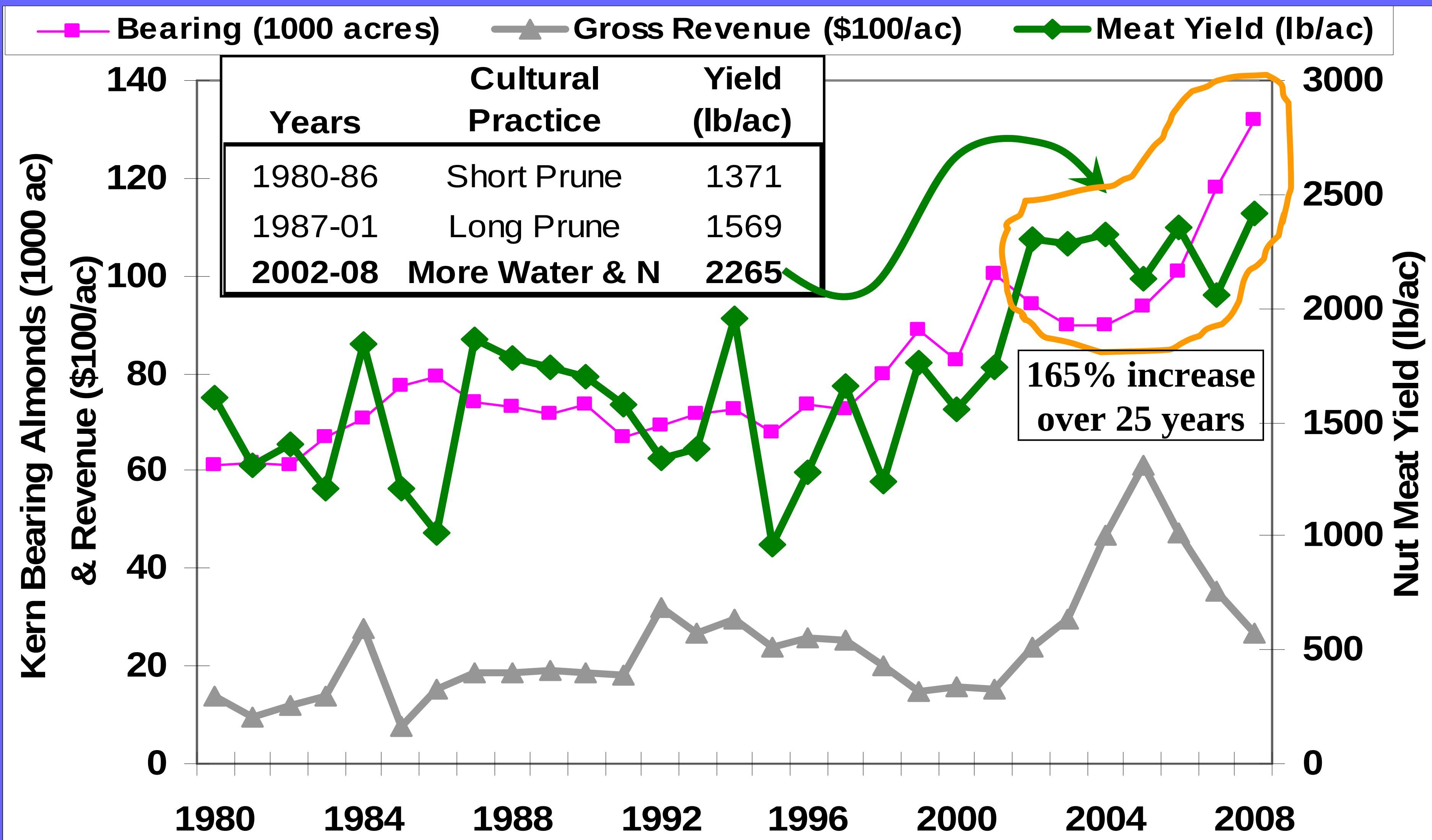
Reduced N applications always maintained July leaf tissue >2% N.

Lampinen, B., T.Dejong, S.Weinbaum, S.Metcalf, C. Negron, M.Viveros, J. McIlvane, N.Ravid, and R.Baker. 2007. Spur dynamics and almond productivity. CA Almond Board 2006 Conference Proceedings, 18pp.

Do almonds really need as much water as alfalfa – 52 to 56 inches? The old recommendation was 42-45 inches?

What's the right ET?

Changes in Kern County almond yield and acreage from 1980-2008



Years	Cultural Practice	Yield (lb/ac)
1980-86	Short Prune	1371
1987-01	Long Prune	1569
2002-08	**More Water & N**	**2265**

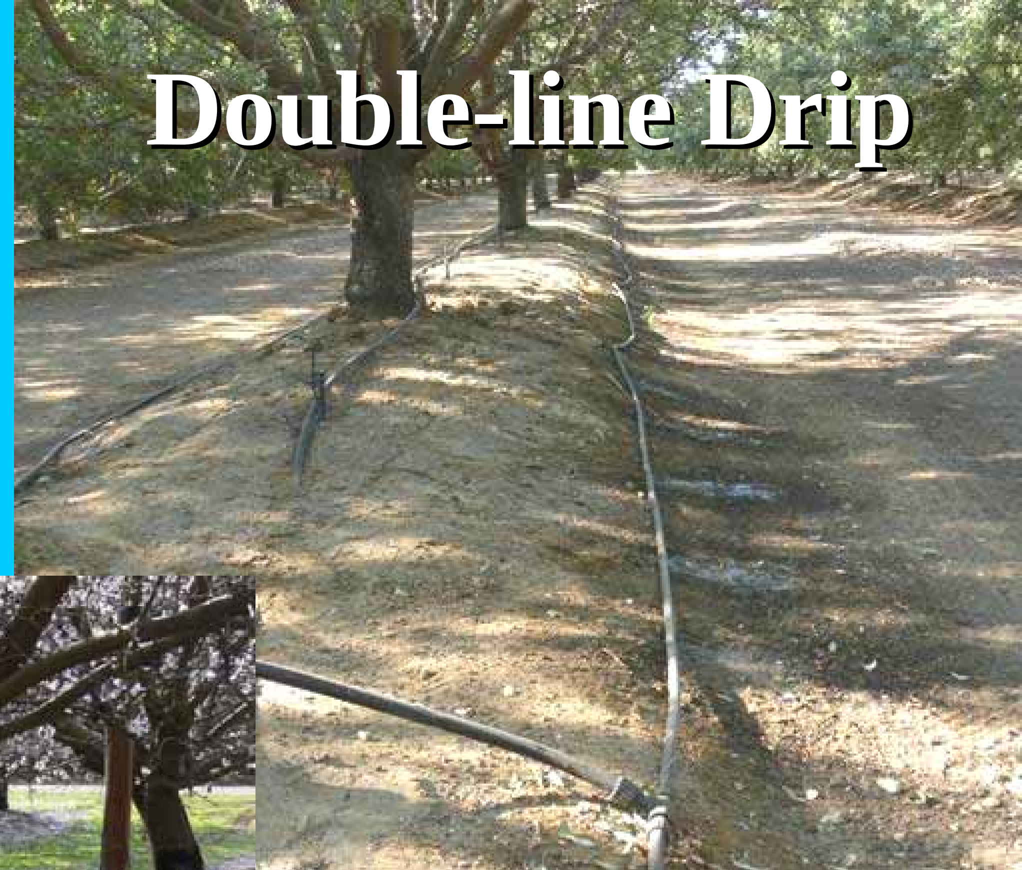
UNIVERSITY of CALIFORNIA
COOPERATIVE EXTENSION

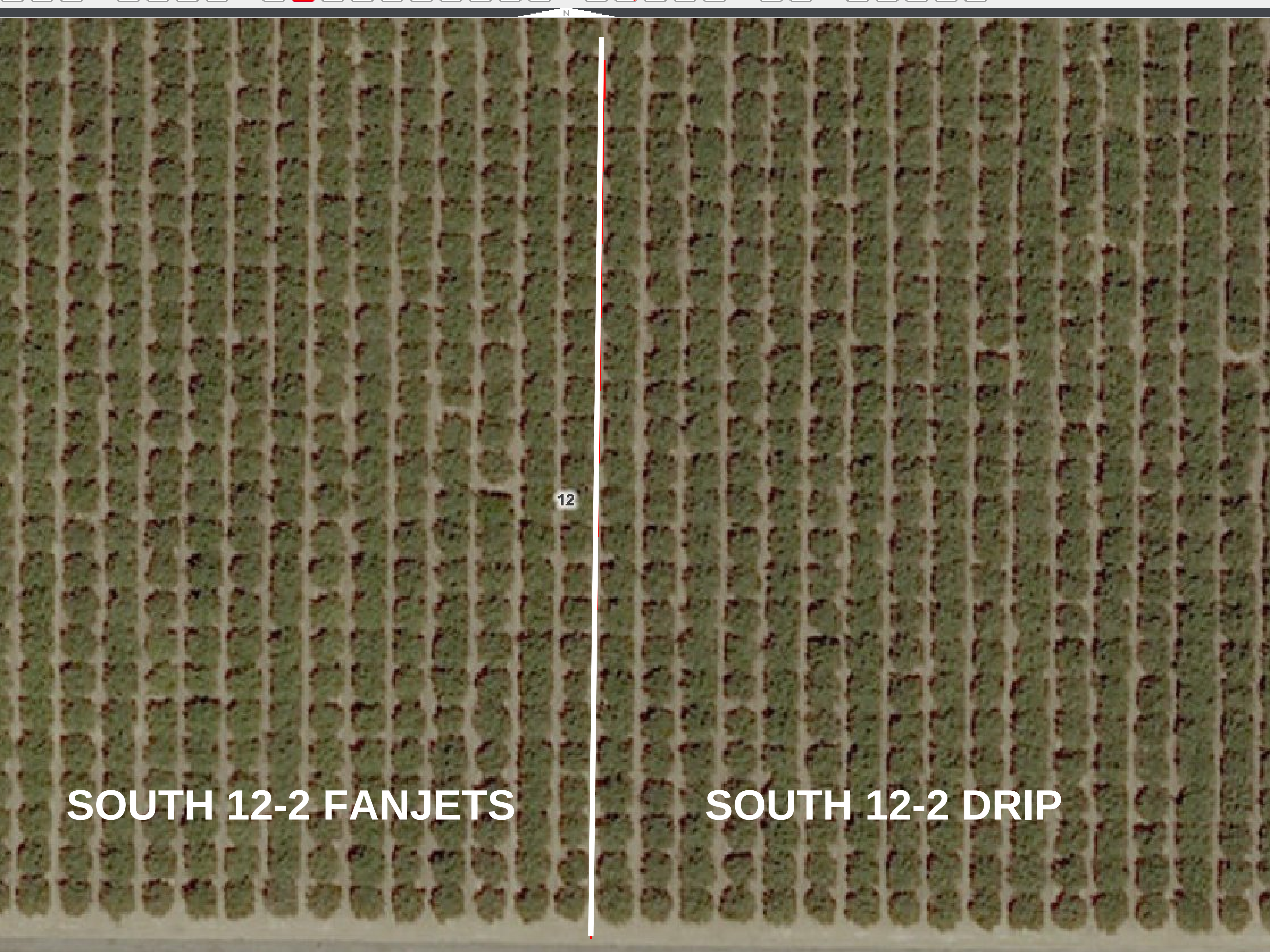
Fertigation: Case study of interaction of water and nutrient management in almonds: 2008-2012

Blake Sanden – Irrigation & Agronomy, Kern County

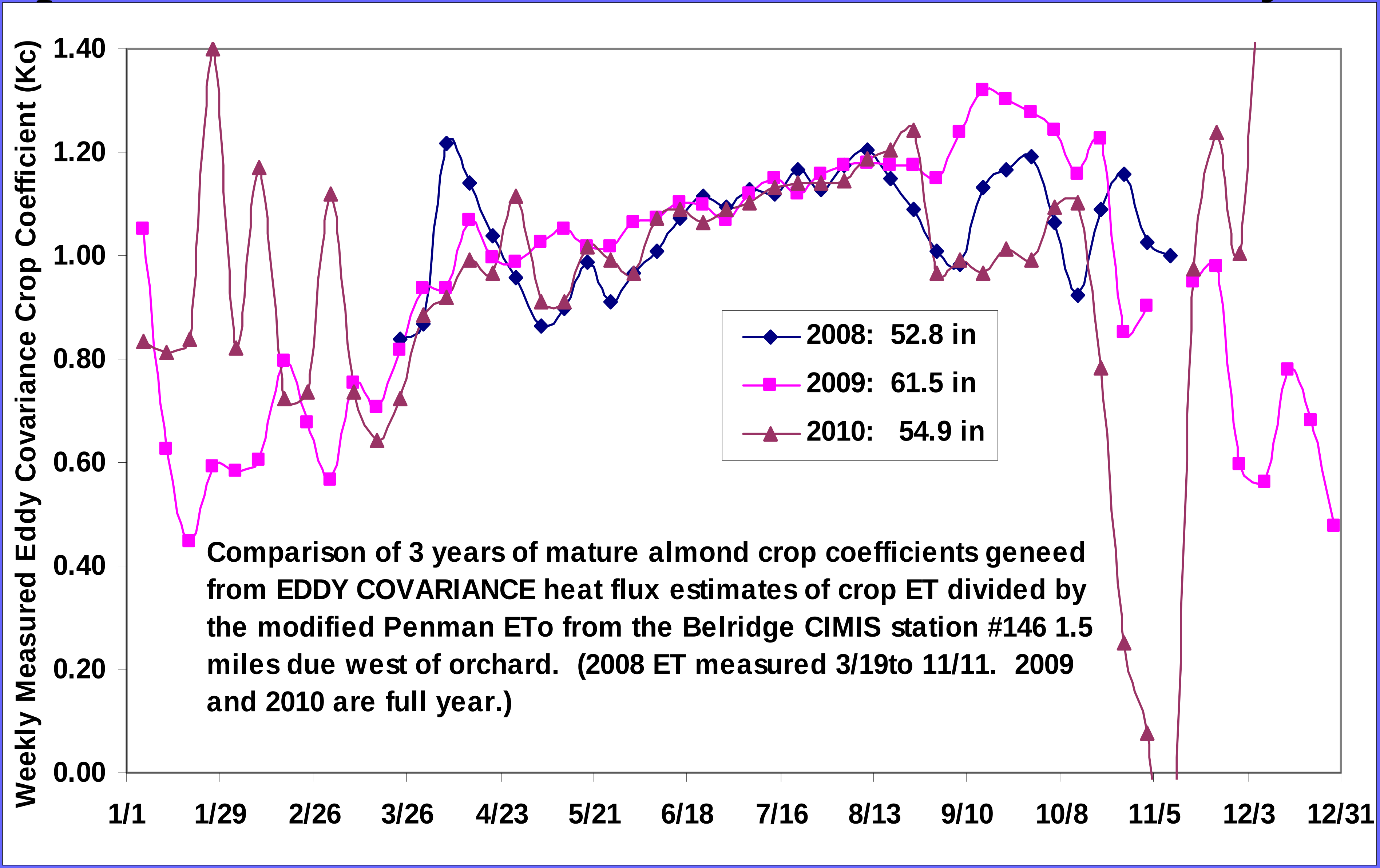
Collaborative USDA Specialty Crops and California Almond Board Project

Measuring nutrient and irrigation response under …

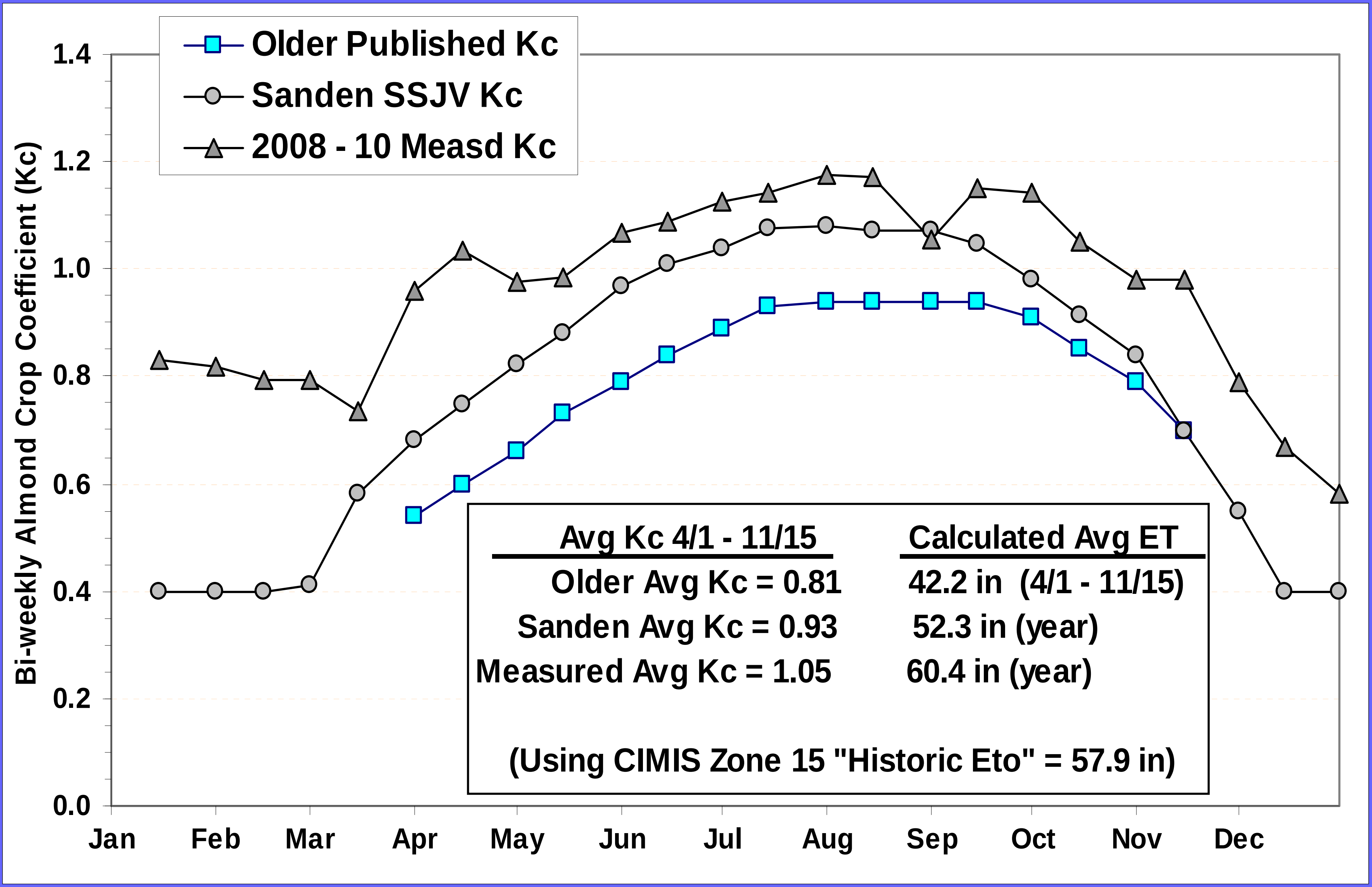



12
SOUTH 12-2 FANJETS
SOUTH 12-2 DRIP

3 years of weekly measured Kc's for high production almonds in Western Kern County



What are optimal almond Kc's and crop ET?

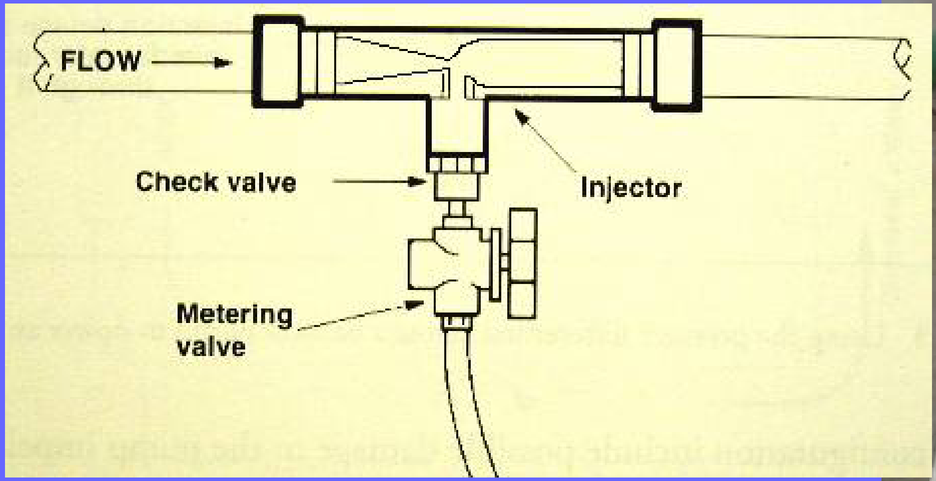


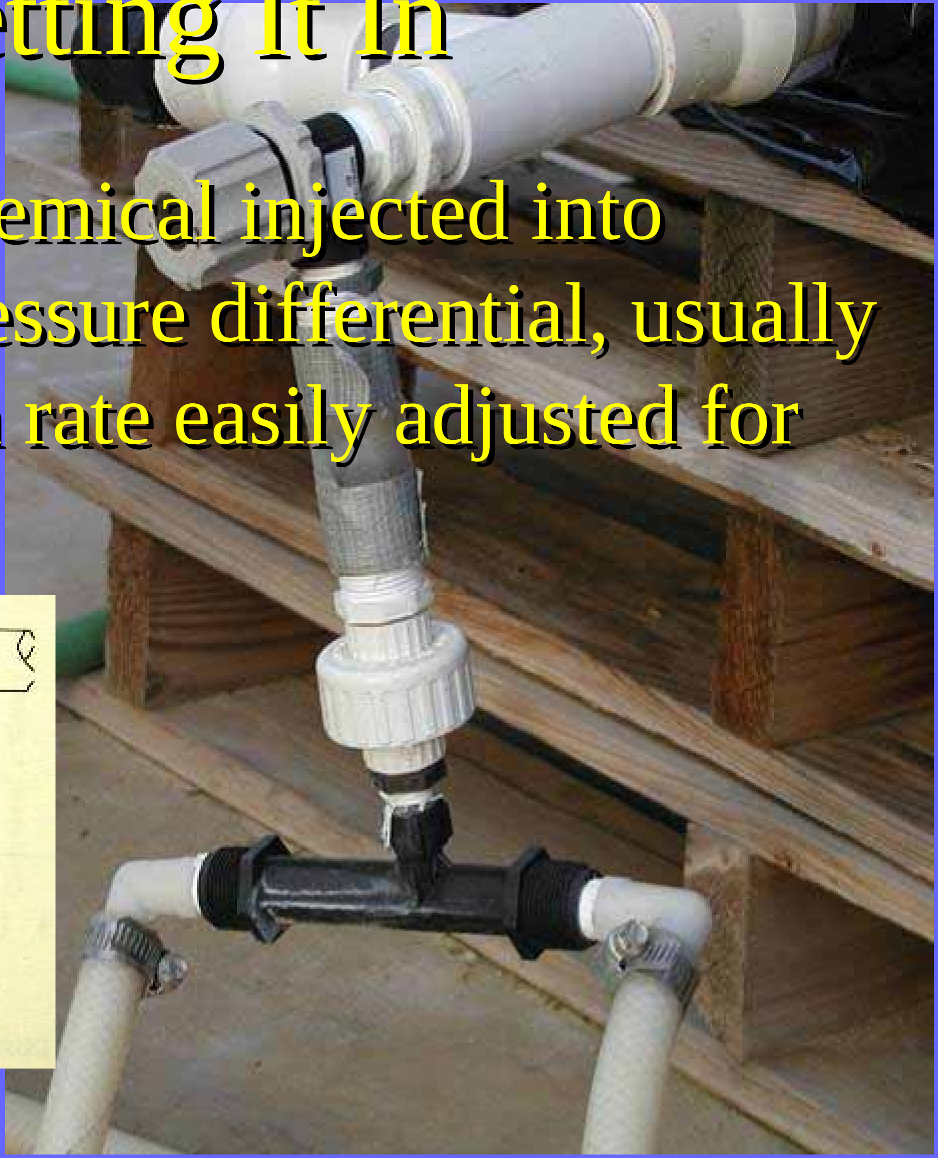
4 3-point sermon:

- Understanding & monitoring soil water holding characteristics
- Crop water requirements (ET), CIMIS
- NPK nutrient requirements for almonds & fertigation
- Irrigation & crop salinity tolerance

Chemigation: Getting It In

- **<u>Venturi (Mazzei)</u>:** chemical injected into vacumn created by pressure differential, usually fertilizer, but injection rate easily adjusted for small volume





Chemigation: Getting It In

- **Multi-stage diaphragm**

Chemigation: Getting It In

- **<u>Single-stage diaphragm pump on roll-up nurse tank</u>**


CHLORINE
CLORO


RAIN BIRD

Injection nipple on well casing dribbling chemicals directly into groundwater.

Chemigation Initiative

REQUIRED CHEMIGATION SAFETY DEVICES

Equipment Required on the Irrigation Pipeline

(A) Check Valve

(B) Low Pressure Drain

(C) Air/Vacuum Relief Valve

Alternative for (A), (B), and (C): Gooseneck Pipe Loop

(D) Pressure Switch

Required Power and System Interlocks

(E) Interlocking System Controls

Equipment Required on the Injection Line

(F) Solenoid Operated Valve

Alternatives:

a. 10-psi Check Valve*

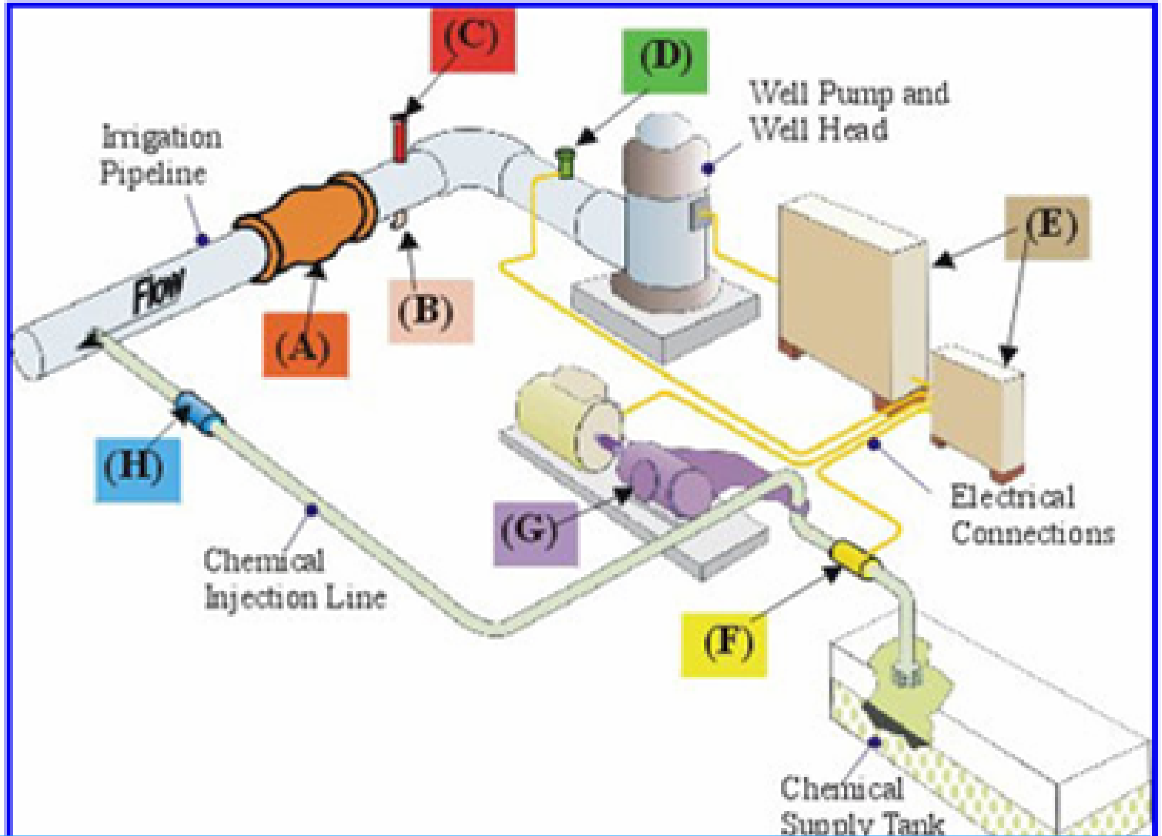
b. Hydraulically Operated Valve

c. Vacuum Relief Valve*

(G) Chemical Injection Pump

Alternative: Venturi Injector

(H) Injection Line Check Valve**

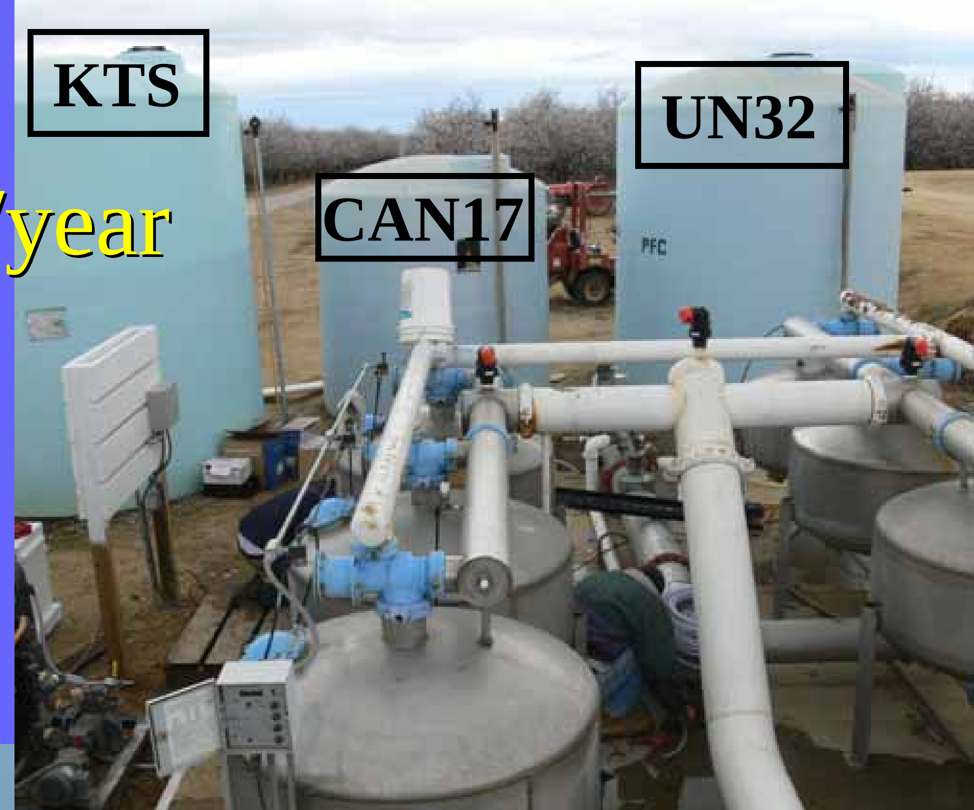


Chemigation/Backflow Prevention http://www.cdpr.ca.gov/docs/gwp/chem/chemdevices.htm

Main fertility trial:

Direct injection 4 times/year

Bloom	20%
April	30%
June	30%
Post Harvest	20%



Fertilizer Treatments for Fertigation/ET Trial

Fertigate 4 times/year: 20% February, 30% April, 30% June, 20% August

A: 125 LB UAN + 125 LB KSOP banded (one application) + 75 LB KTS

B: 200 LB UAN + 125 LB KSOP banded (one application) + 75 LB KTS

C: 275 LB UAN + 125 LB KSOP banded (one application) + 75 LB KTS

D: 350 LB UAN + 125 LB KSOP banded (one application) + 75 LB KTS

E: 125 LB CAN17 + 125 LB KSOP banded (one application) + 75 LB KTS

F: 200 LB CAN17 + 125 LB KSOP banded (one application) + 75 LB KTS

G: 275 LB CAN17 + 125 LB KSOP banded (one application) + 75 LB KTS

H: 350 LB CAN17 + 125 LB KSOP banded (one application) + 75 LB KTS

I: 275 LB UAN + 60 LB KSOP banded (one application) + 40 LB KTS

J: 275 LB UAN + 180 LB KSOP banded (one application) + 120 LB KTS

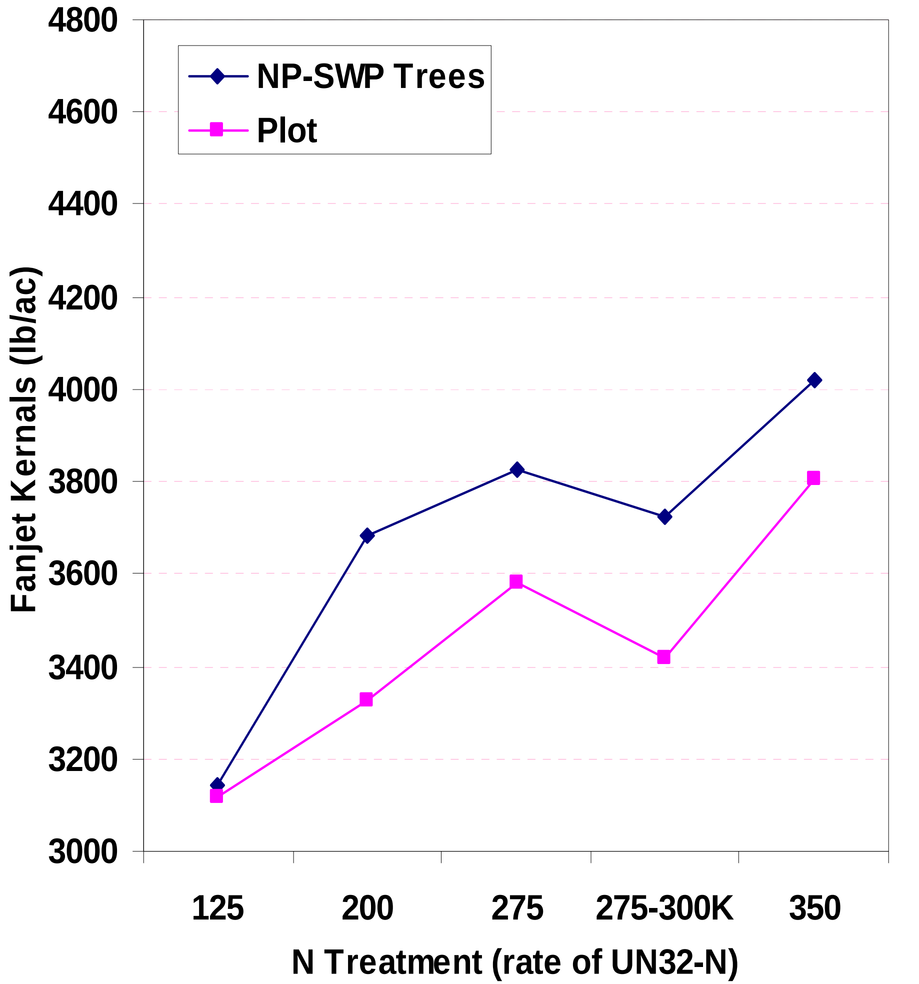
K: 275 LB UAN + 200 LB KSOP banded (one application)

L: 275 LB UAN + 200 LB KCL

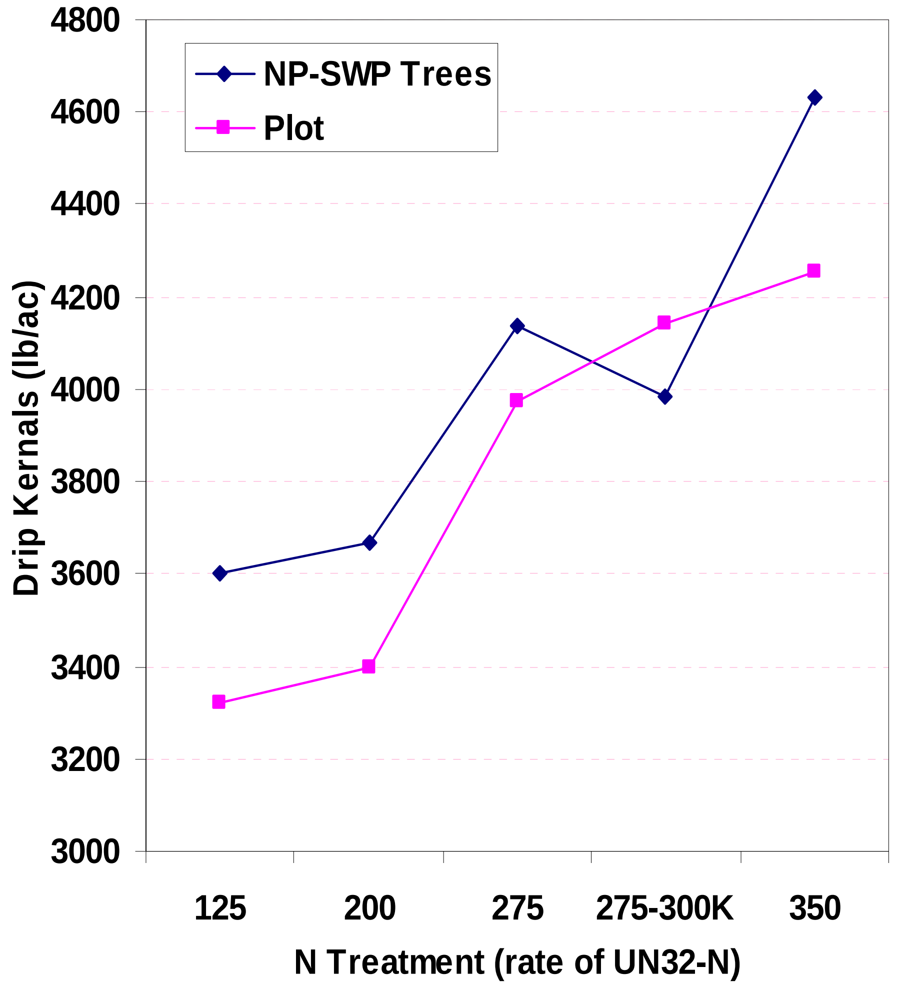
Winter banding of sulphate of potash (K_2SO_4, or simply SOP, @ 125 lb/ac K)

2010 YIELDS BY FERTILIZER RATE

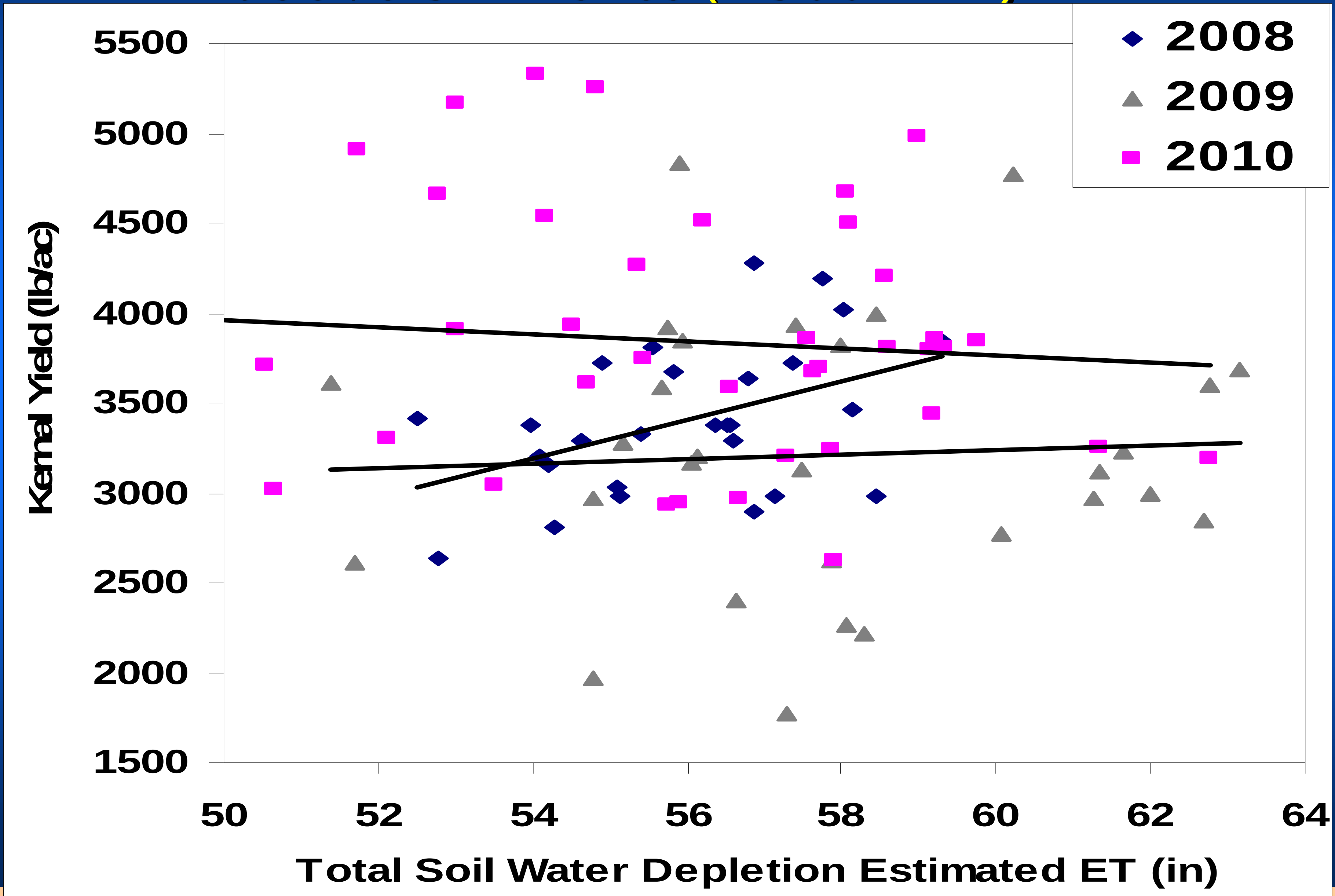
FANJET



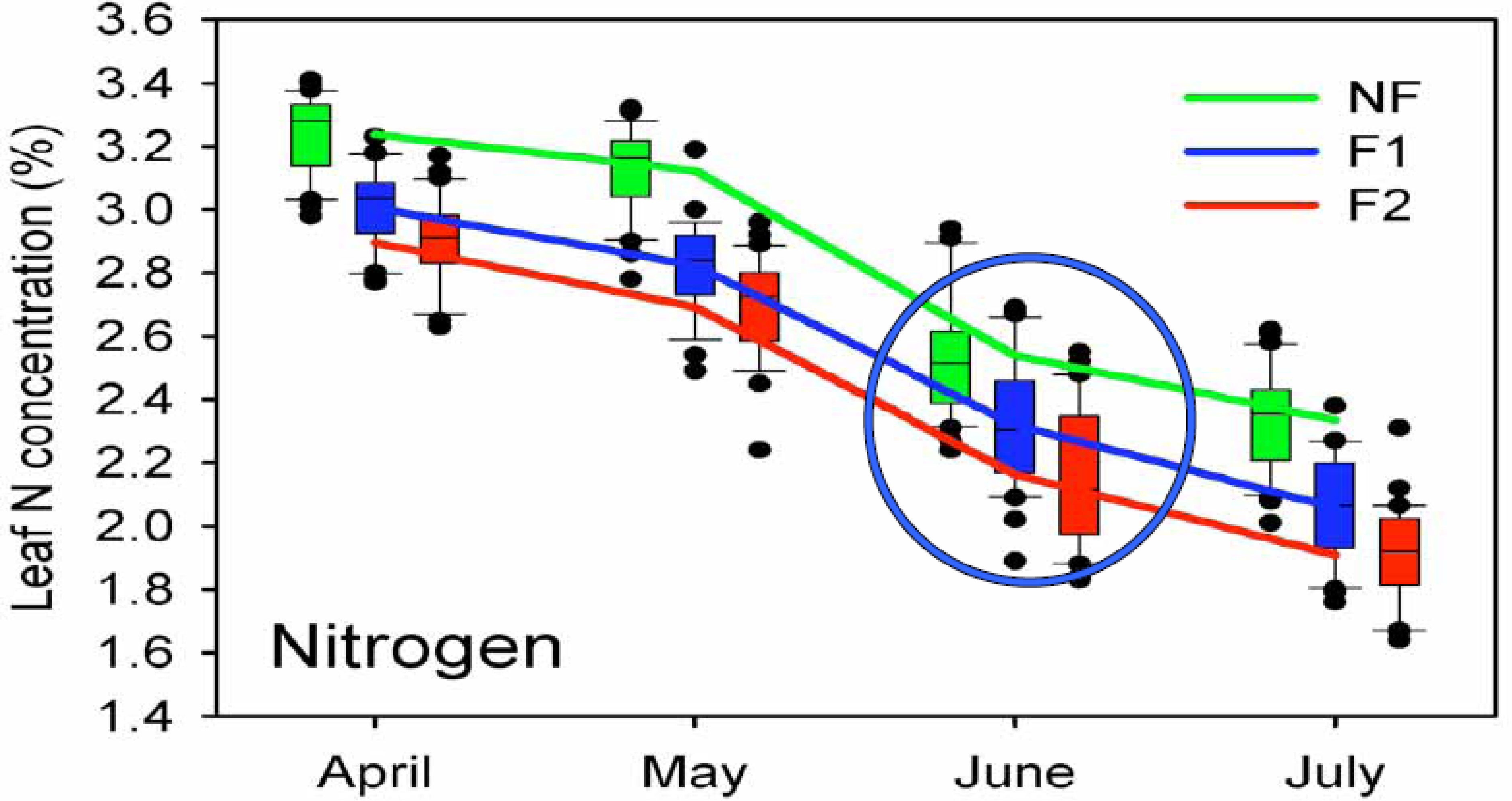
DRIP



Kernal yield and water use not correlated above 51 inches (1300 mm) ET



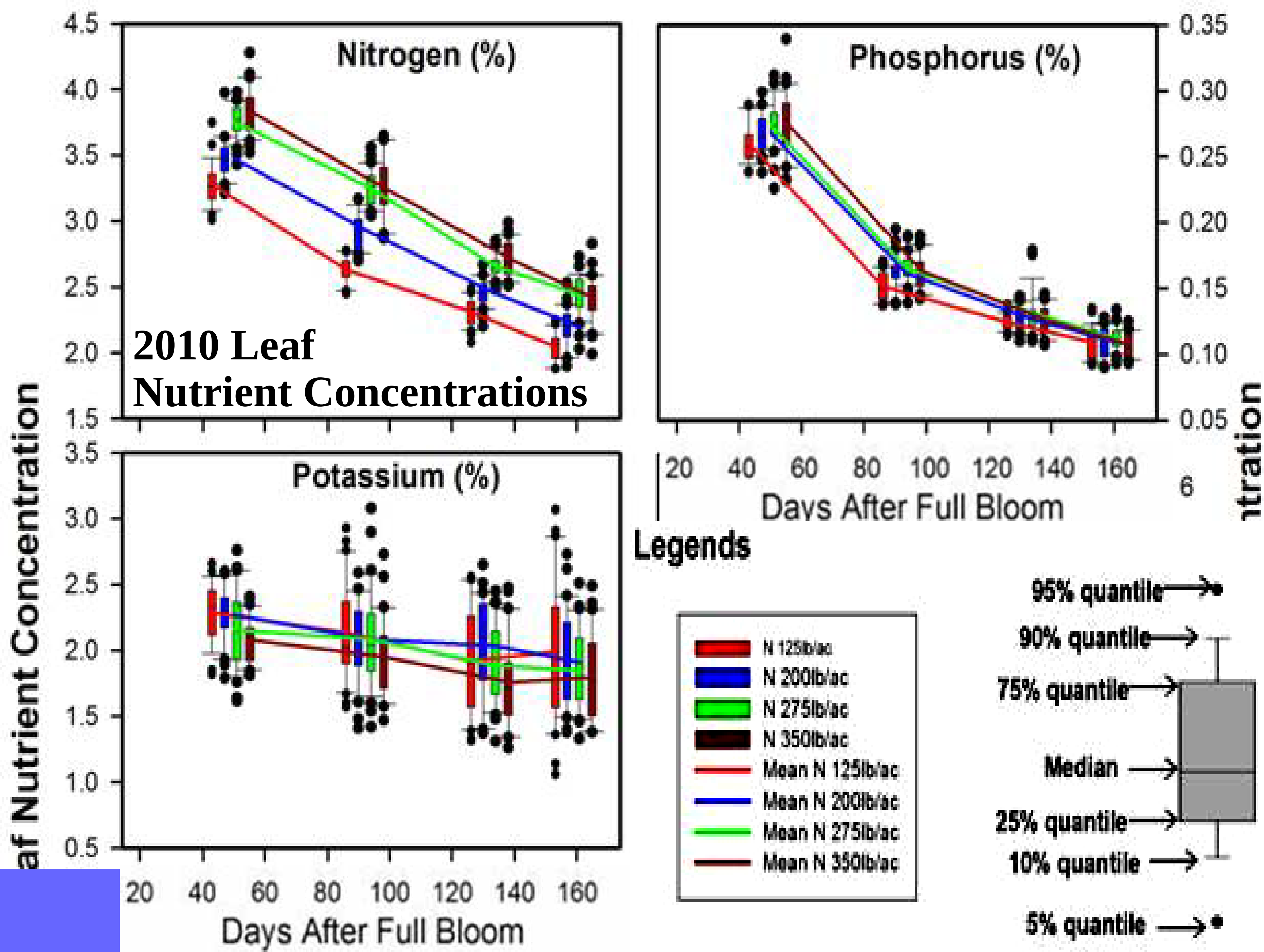
Critical Values are based on July/August sample. Early season CV's have not been validated.

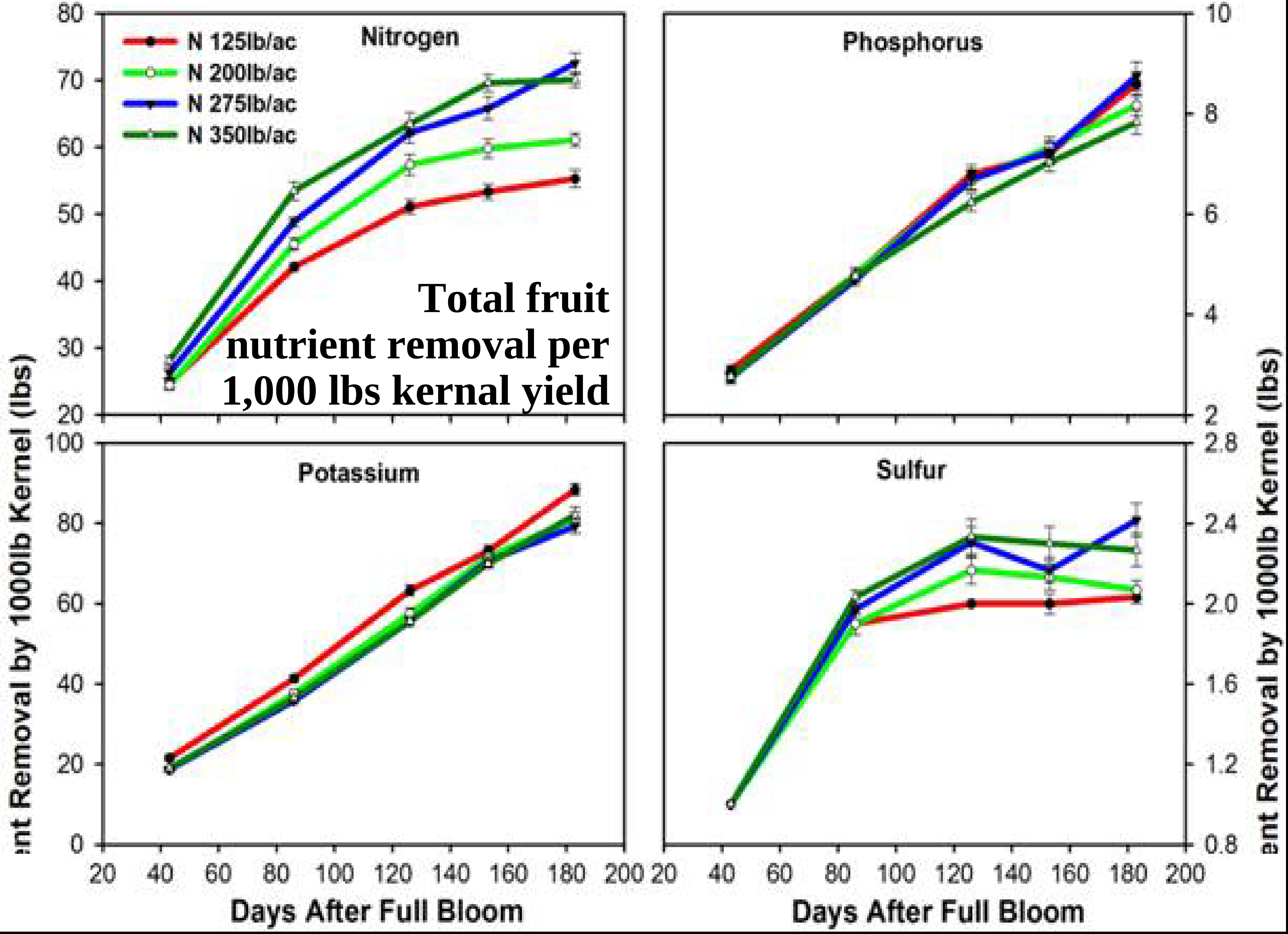


Current Practice: Late summer sample. Too late for current season response. Too early for next season planning (yield potential is defined by winter and spring weather)

Challenge: Develop early season sampling and interpretation methodologies.

2010 Leaf Nutrient Concentrations

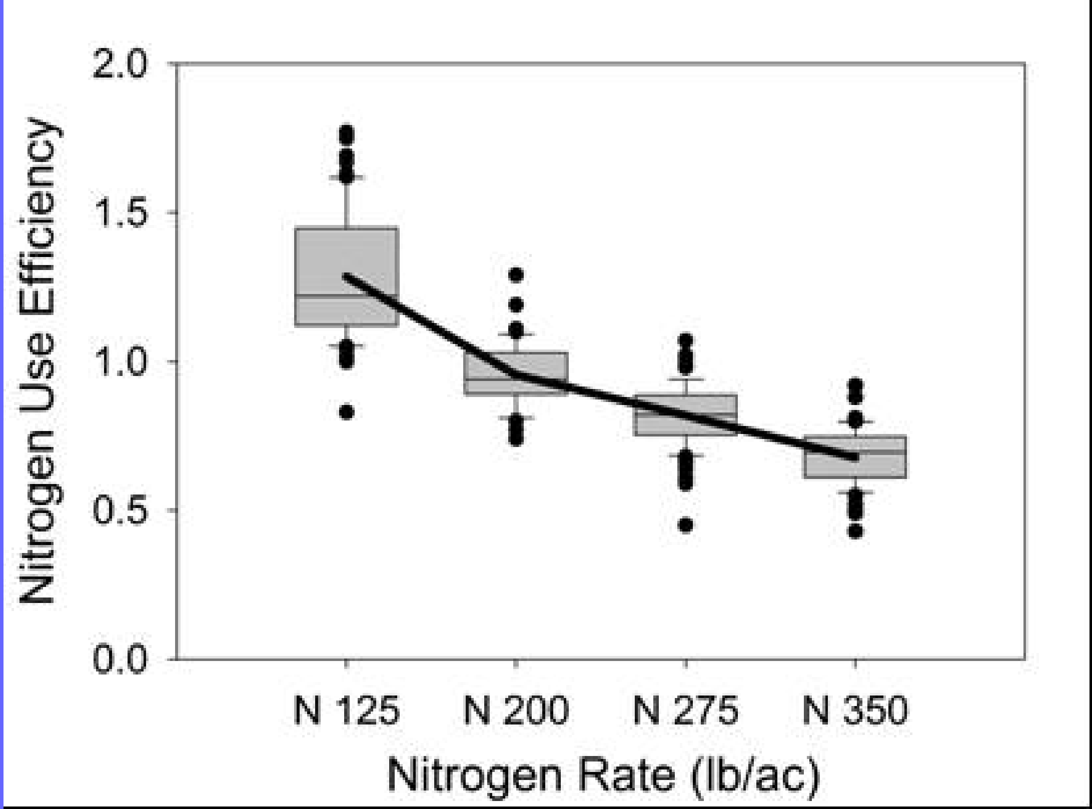



Total fruit nutrient removal per 1,000 lbs kernal yield
Nitrogen
N 125lb/ac
N 200lb/ac
N 275lb/ac
N 350lb/ac
Phosphorus
Potassium
Sulfur
ent Removal by 1000lb Kernel (lbs)
ent Removal by 1000lb Kernel (lbs)
Days After Full Bloom
Days After Full Bloom

	N Rate (lb/ac)		4,000 lb
	125	350	Kernals
N	53	66	264
P	8.4	7.4	29.6
K	80	75	300

Pounds of nutrient removed in whole fruit per 1000 lbs of kernals

Actual cumulative N-use efficiency from 2008 to 2010 for all N rates (81% NUE @ 275 lb/ac N)



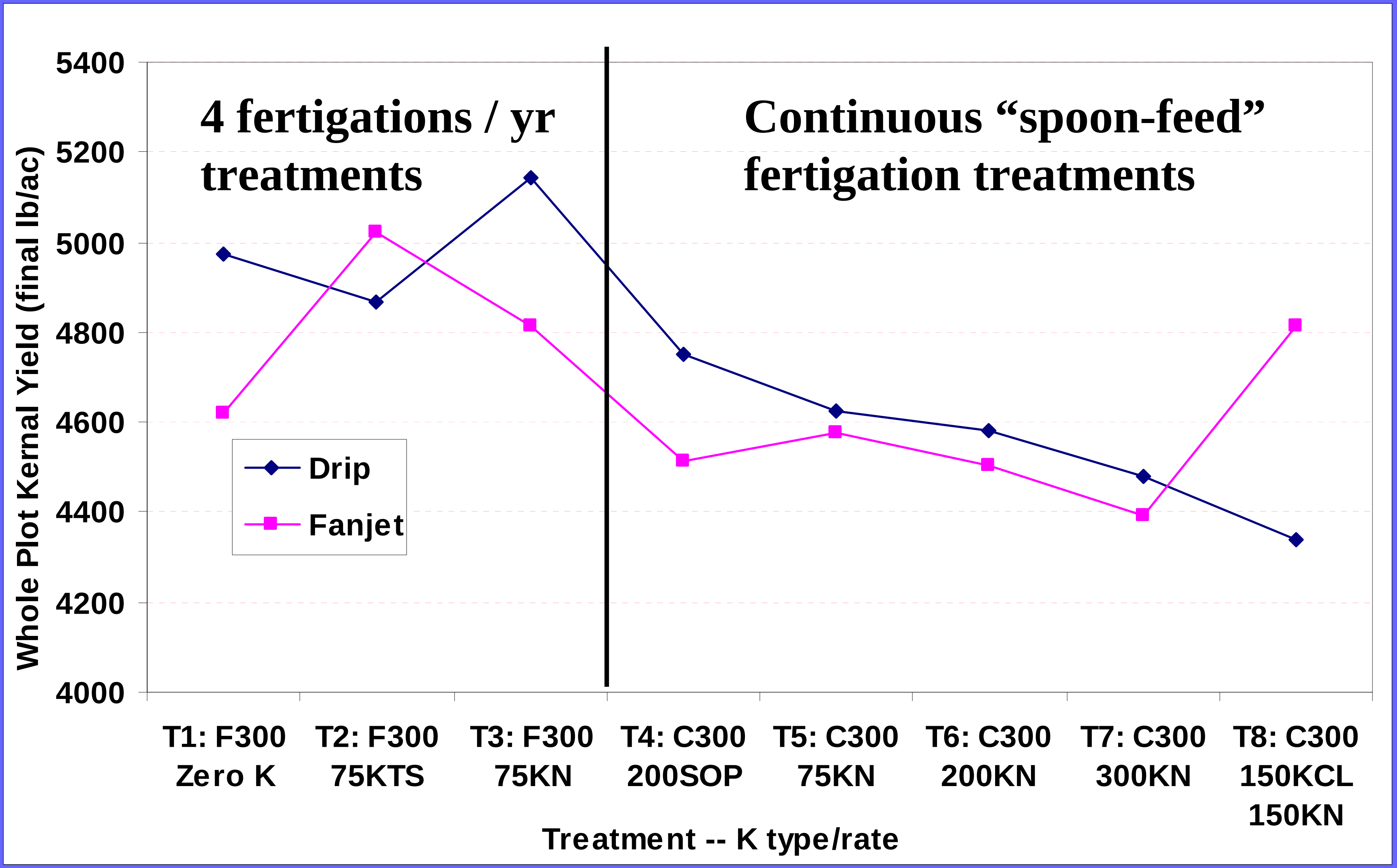
2011 installation of 5 Grundfos dosing pumps for “spoon-feed” fertigation trial

VARIABLE K RATE KNO3 TRIAL

Treatments A, B, C recieve 4 "episodic (F)" fertigations over the season @ 20% Feb, 30% April, 30% June, 20% post harvest. Treatments D, E, F, G and H are continuous or "spoon-feed (C)" fertilizer treatments with fertilizer injections every irrigation, with 10% applied post-harvest. ALL TREATMENTS RECIEVE A TOTAL OF 300 LB/AC NITROGEN.

F300-0	T1: No K, 300 lbs N as UAN
F300-75KTS 125 SOP	T2: 200 lb K = 125 SOP band + 75 KTS, 300 lb UAN (Grower Standard)
F300-75KN 125 SOP	T3: 200 lb K = 125 SOP band + 75 KNO3, 273 UAN + 27 KNO3
C300-200SOP	T4: 200 lb K = SOP dissolved in mix tank, 300 lb UAN (Manifold 1)
C300-75KN	T5: 200 lb K = 125 SOP band + 75 KNO3, 273 UAN + 27 KNO3 (Manifold 2)
C300-200KN	T6: 200 lb K = KNO3, 193 UAN + 107 KNO3 (Manifold 3)
C300-300KN	T7: 300 lb K = KNO3, 128 N UAN + 172 KNO3 (Manifold 4)
C300-150 KCl 150 KNO3	T8: 300 lb K = 150 KCL + 150 KNO3, 248 UAN + 52 KNO3 (Manifold 5)

2011 Nonpareil yields for episodic vs. continuous fertigation



Conclusions

- Know soil AWHC and volumetric storage
- Know net infiltration and/or system application capacity
- Plan irrigations using “normal year” ET and CIMIS – update with real-time soil and tree water status monitoring to maximize yield & efficiency
- Have reasonable estimate of crop nutrient demand given realistic field yield expectations
- Know fertilizer injection rates and match to tree nutrient uptake – most in by July
- Sample leaf tissues and in April using new standards and adjust for deficiencies


Technology is helpful, but the most valuable thing you can put in the field is your shadow …

…because pigeons happen despite our best plans!!

Paul's plan to deliver his Valentine via carrier pigeon goes horribly wrong.