UNIVERSITY of CALIFORNIA COOPERATIVE EXTENSION

Salinity Red Flags in Growing Pistachios

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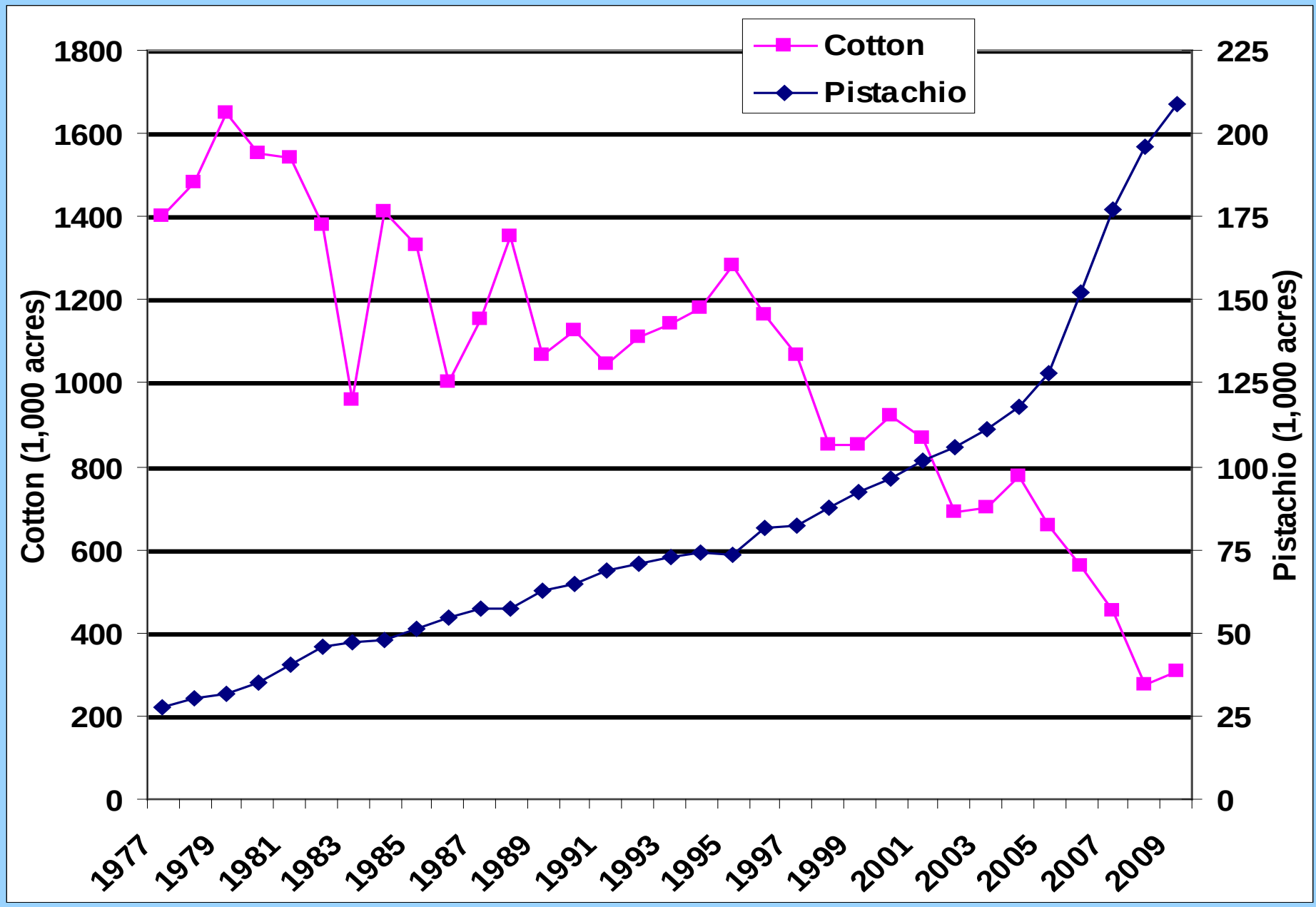
2011 Annual Statewide Pistachio Day
January 13, 2011 Visalia, CA

(Why are we still talking about salt?)

"Edjyikashun is the process of repitishun."

Hodge Black – Arkansan born ag extension entomologist and Kern County UC Cooperative Extension director, 1960-1996

Pistachio acreage has doubled in last 10 years

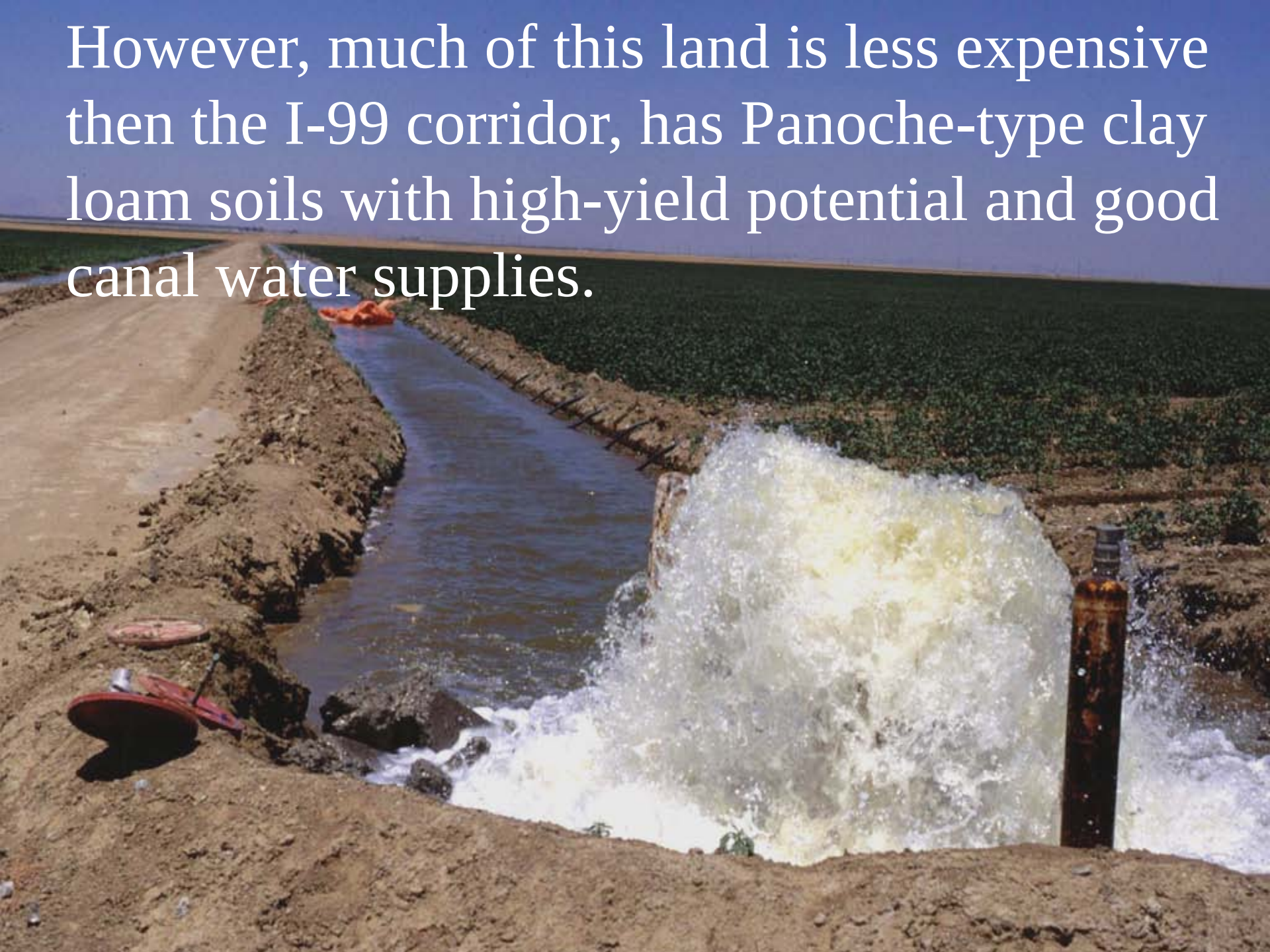


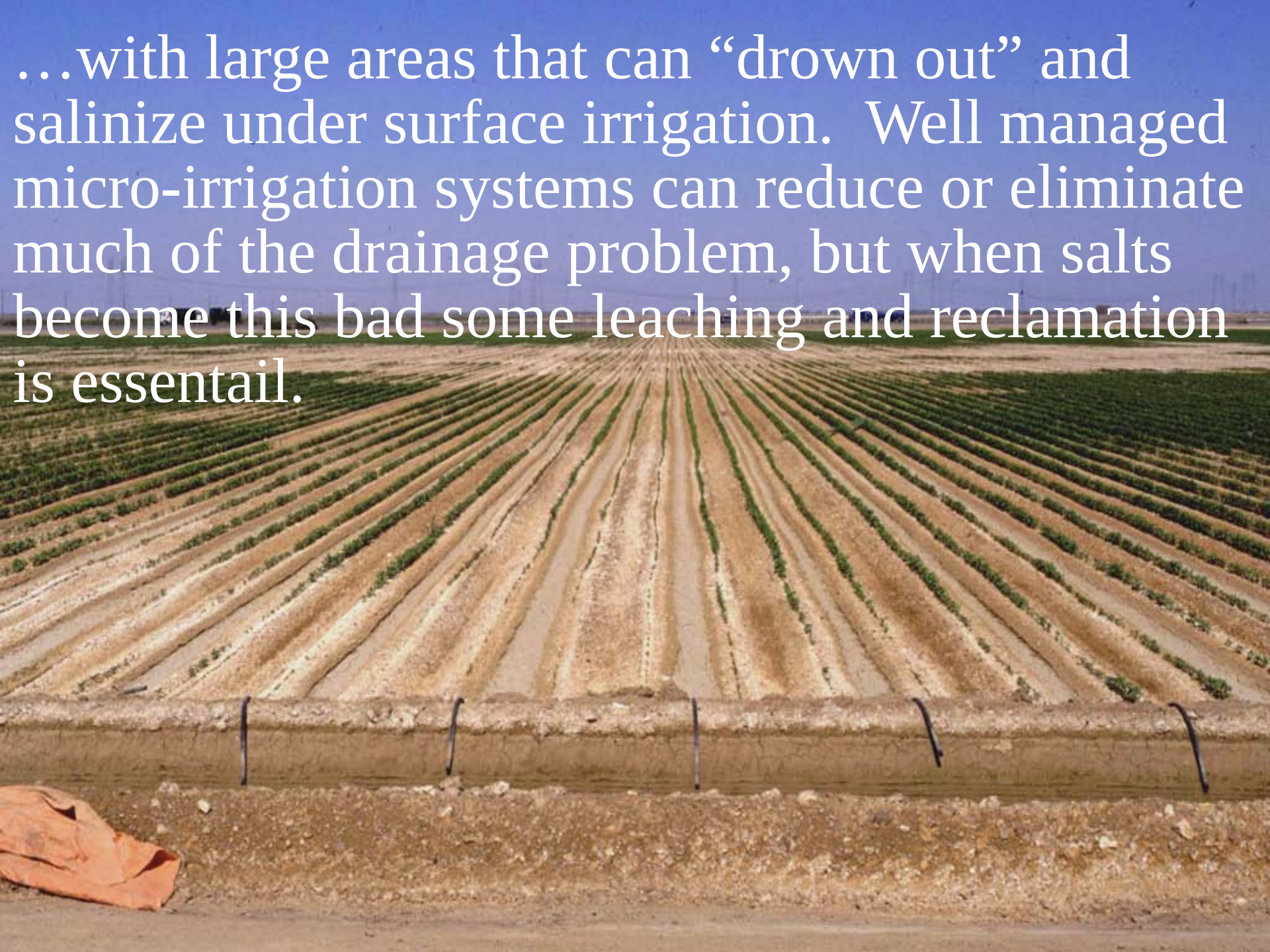
Row crop ground along I-5 & Gooselake Slough -- Ideal for pistachios?

More than ½ million more acres are free of “perched water” but have poor surface soils with excessive silt and sodicity, resulting in “sealing” and poor structure not conducive to optimal root development.


More than ¼ million acres along the Westside of the San Joaquin Valley are affected by poor drainage, perched water and salinity.

However, much of this land is less expensive then the I-99 corridor, has Panoche-type clay loam soils with high-yield potential and good canal water supplies.





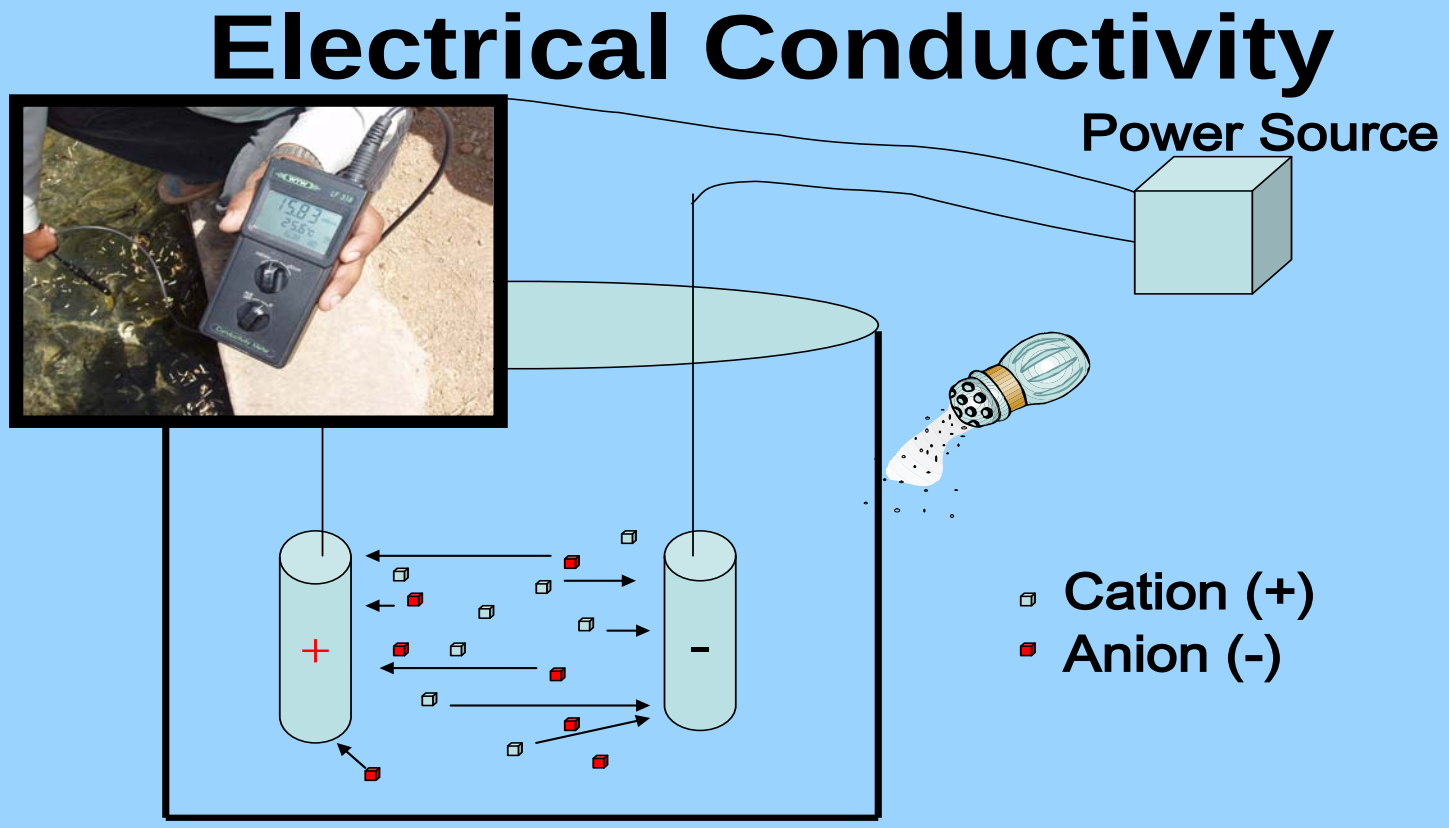
…with large areas that can “drown out” and salinize under surface irrigation. Well managed micro-irrigation systems can reduce or eliminate much of the drainage problem, but when salts become this bad some leaching and reclamation is essentail.


The results in some areas of the
Westside have been spectacular.


But no orchard is perfect

How do we measure salinity?

- **ECw (water) or ECe (soil water extract)**
  - **mmhos/cm = dS/m = 640 ppm TDS**
    - **Water – Ion concentration, temperature (25ºC)**
    - **Soil – distilled water extract –> underestimates the actual pore water salinity**



No marginal burn on 0.7 dS/m UCB Rep 1 (9/16/02)

Marginal burn on 0.7 dS/m UCB Rep 2 (9/16/02)


0.7 dS/m
10/13/00


8 dS/m
10/13/00

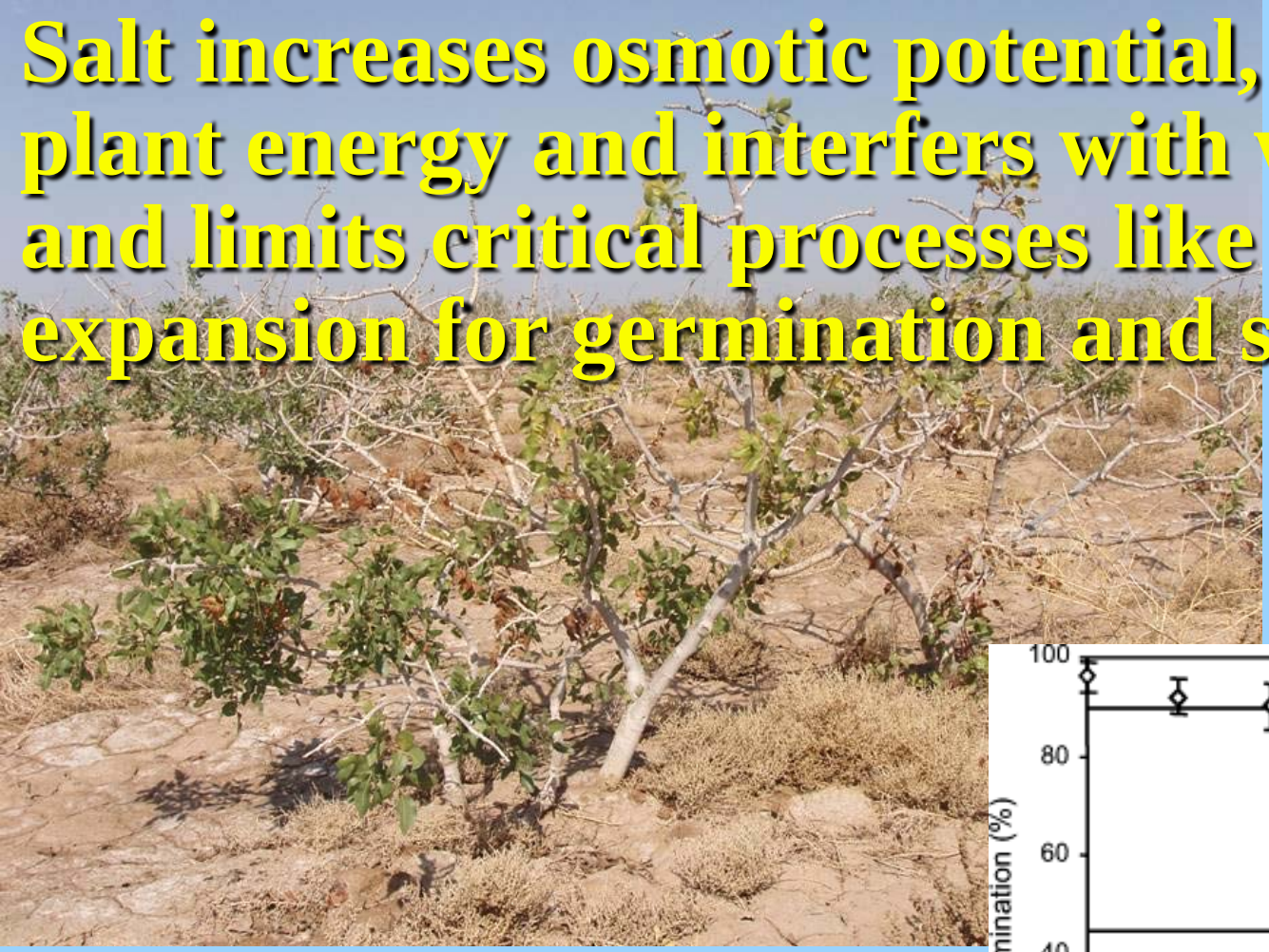
WHY DO WE WORRY ABOUT SALT?

Irrigation water EC (15 dS/m), sodium (50 meq/l, 1150 ppm), chloride (65 meq/l, 2301ppm) and boron (15 ppm) burn on sprinkler irrigated cotton.

Salt and/or specific ion accumulation kills plant tissue

Boron, chloride and sodium accumulation killing marginal leaf areas at end of season.

Salt increases osmotic potential, costing the plant energy and interfers with water uptake and limits critical processes like cell expansion for germination and shoot growth.



Pistachios in Iran (above, irrigation EC 25 dS/m)

Decline in sweet clover germination (50% = sodium 4600 ppm)

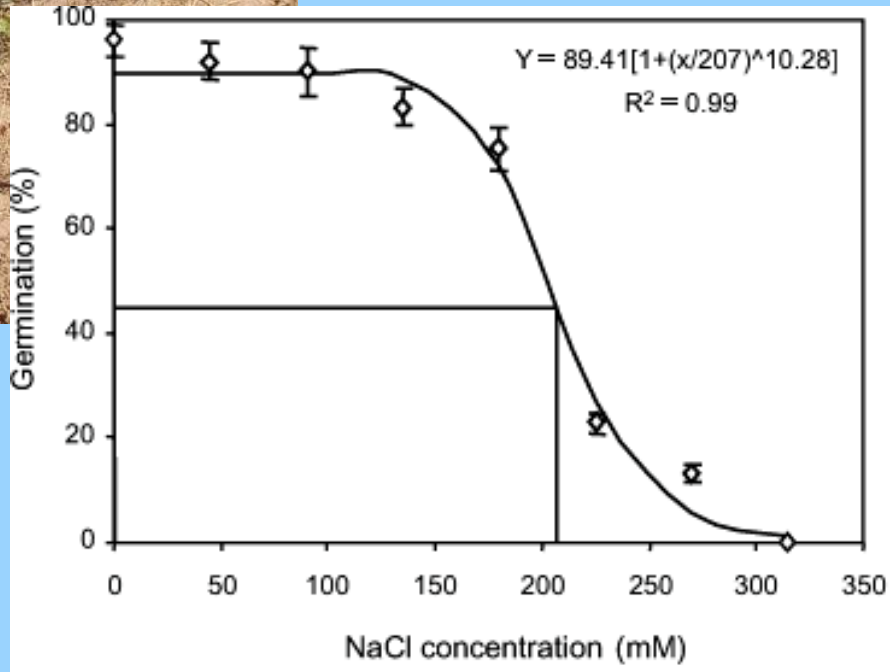
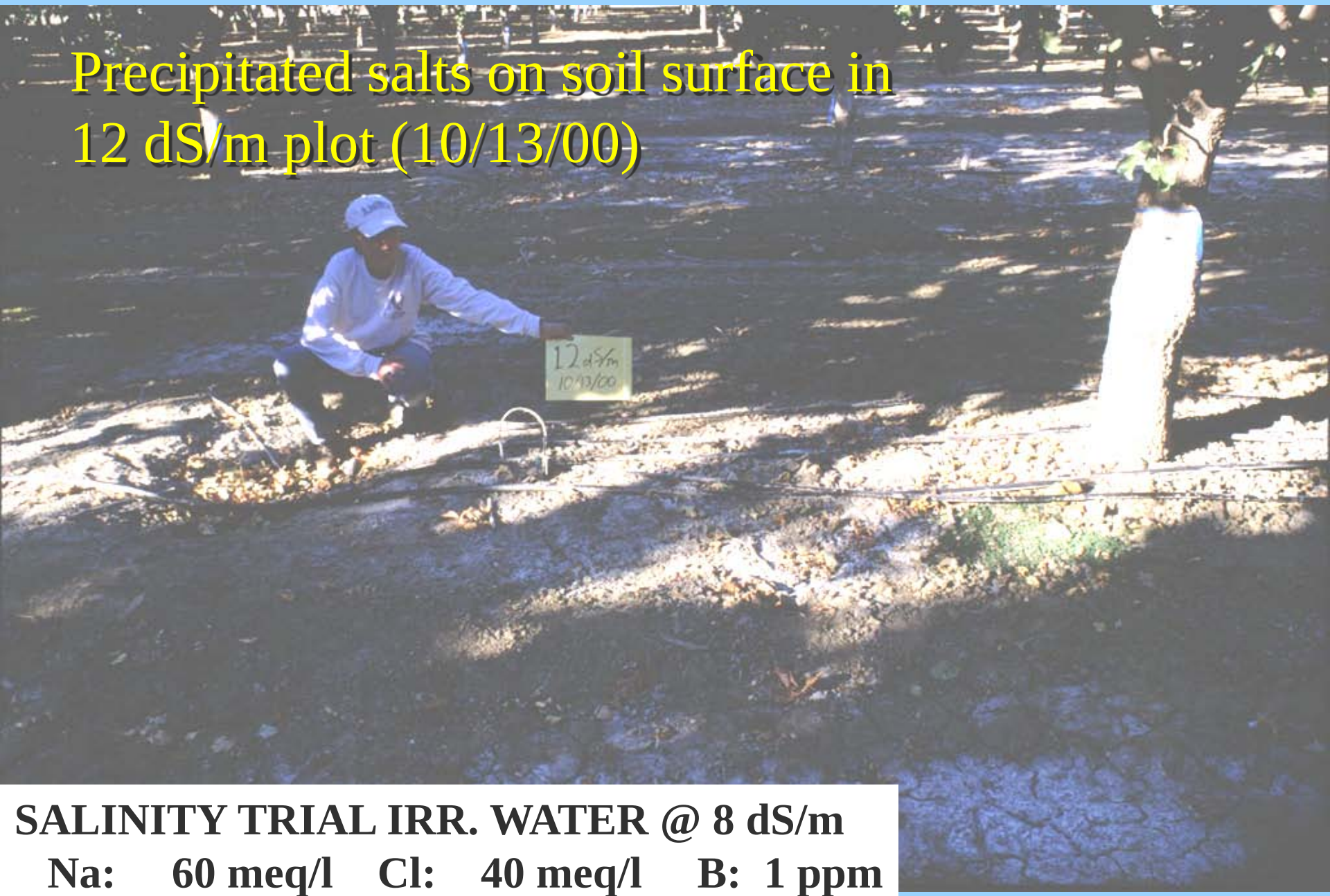


Figure 2 - Effect of NaCl concentration on germination of yellow sweet clover.



Precipitated salts on soil surface in 12 dS/m plot (10/13/00)

SALINITY TRIAL IRR. WATER @ 8 dS/m

Na: 60 meq/l Cl: 40 meq/l B: 1 ppm

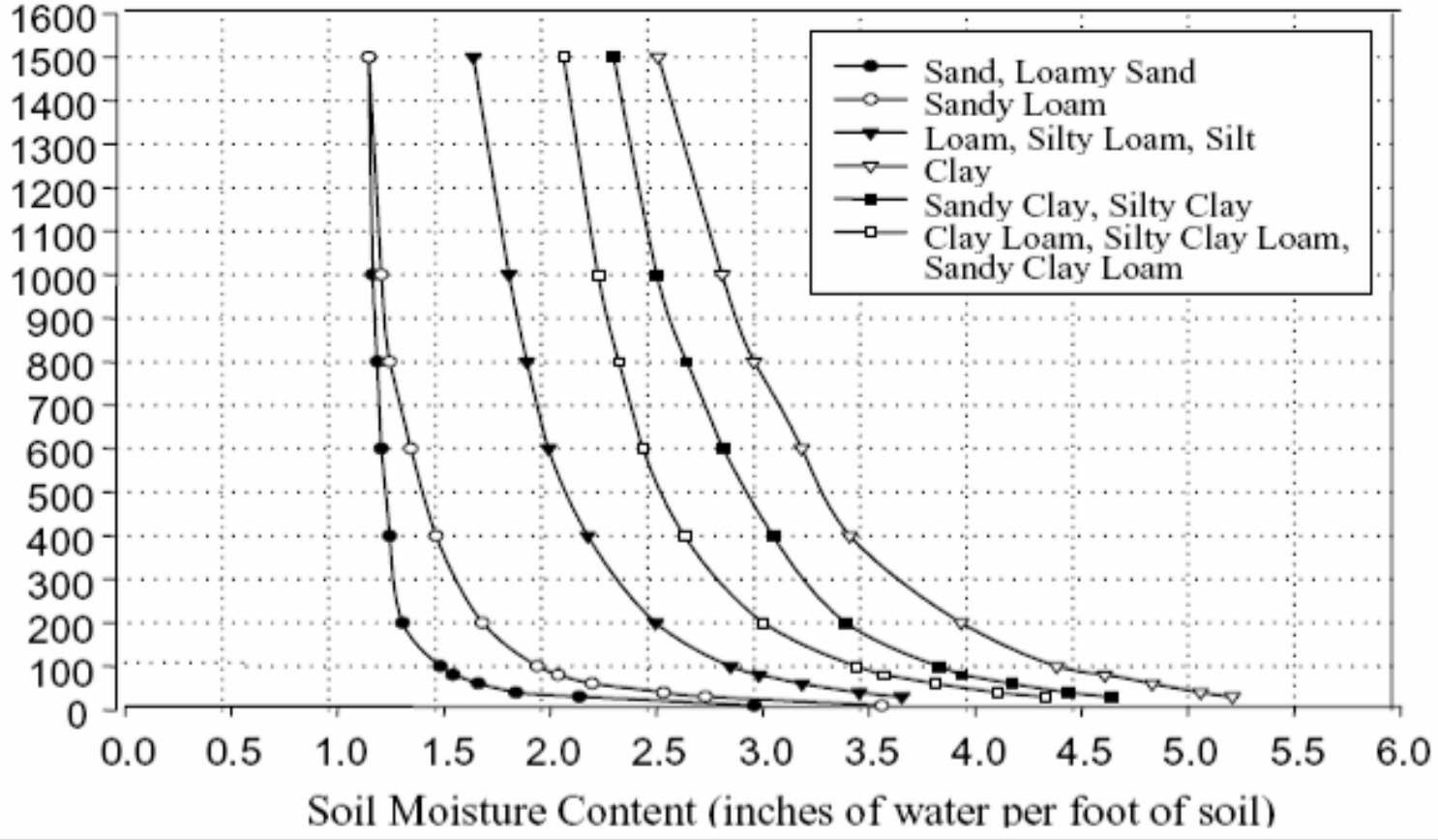
1,380 ppm 1,400 ppm


12 dS/m
10/13/0

INCREASING SALINITY REDUCES WATER UPTAKE / ET

Soil moisture release by texture with no salt impacts

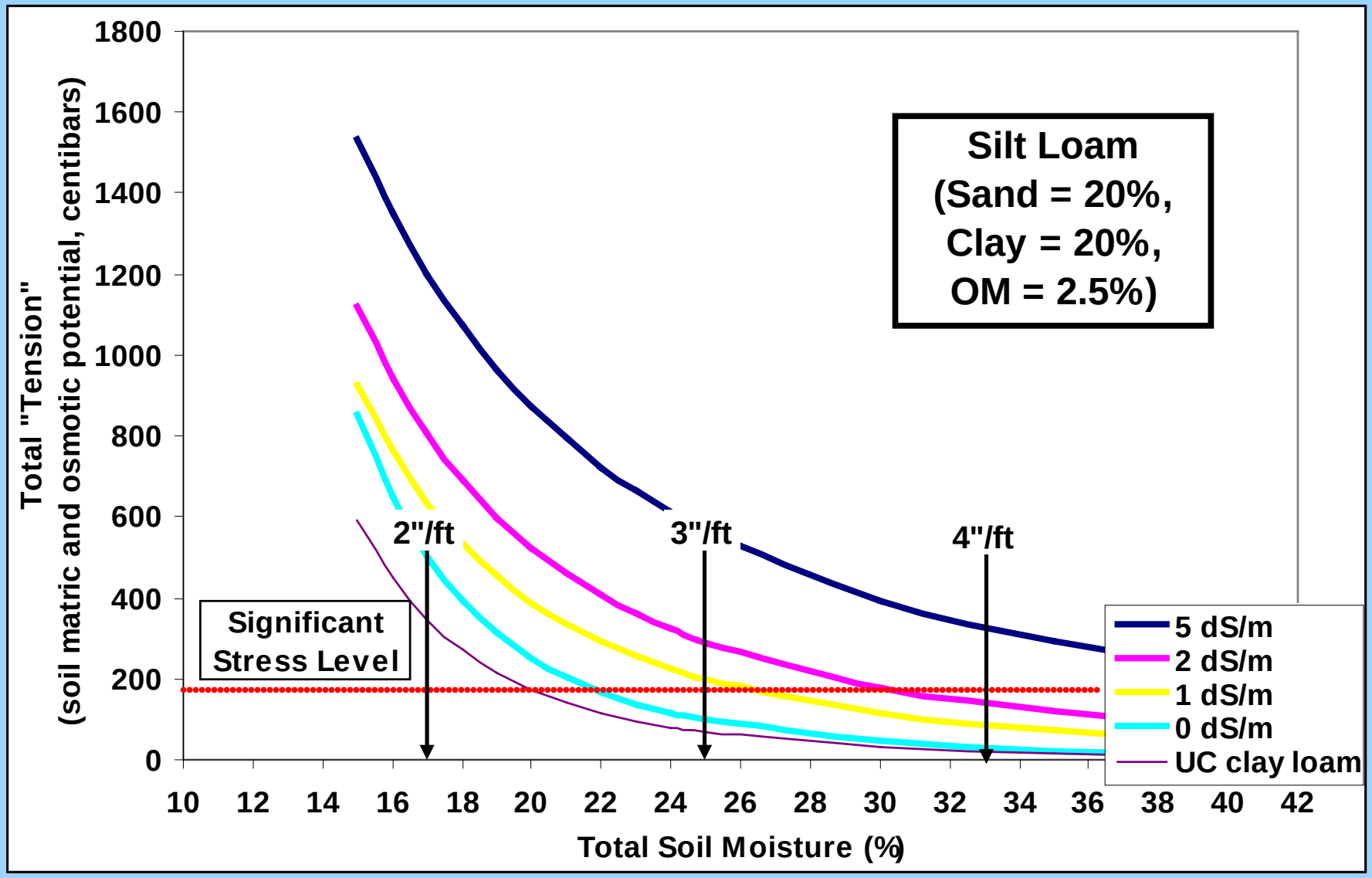
Figure C-1. Soil moisture content versus tension for different soil textures.



(Source: Ley, T., R. G. Stevens, R. R. Topielec, and W. H. Neibling. 1996. *Soil water monitoring and measurement.* PNW475.)

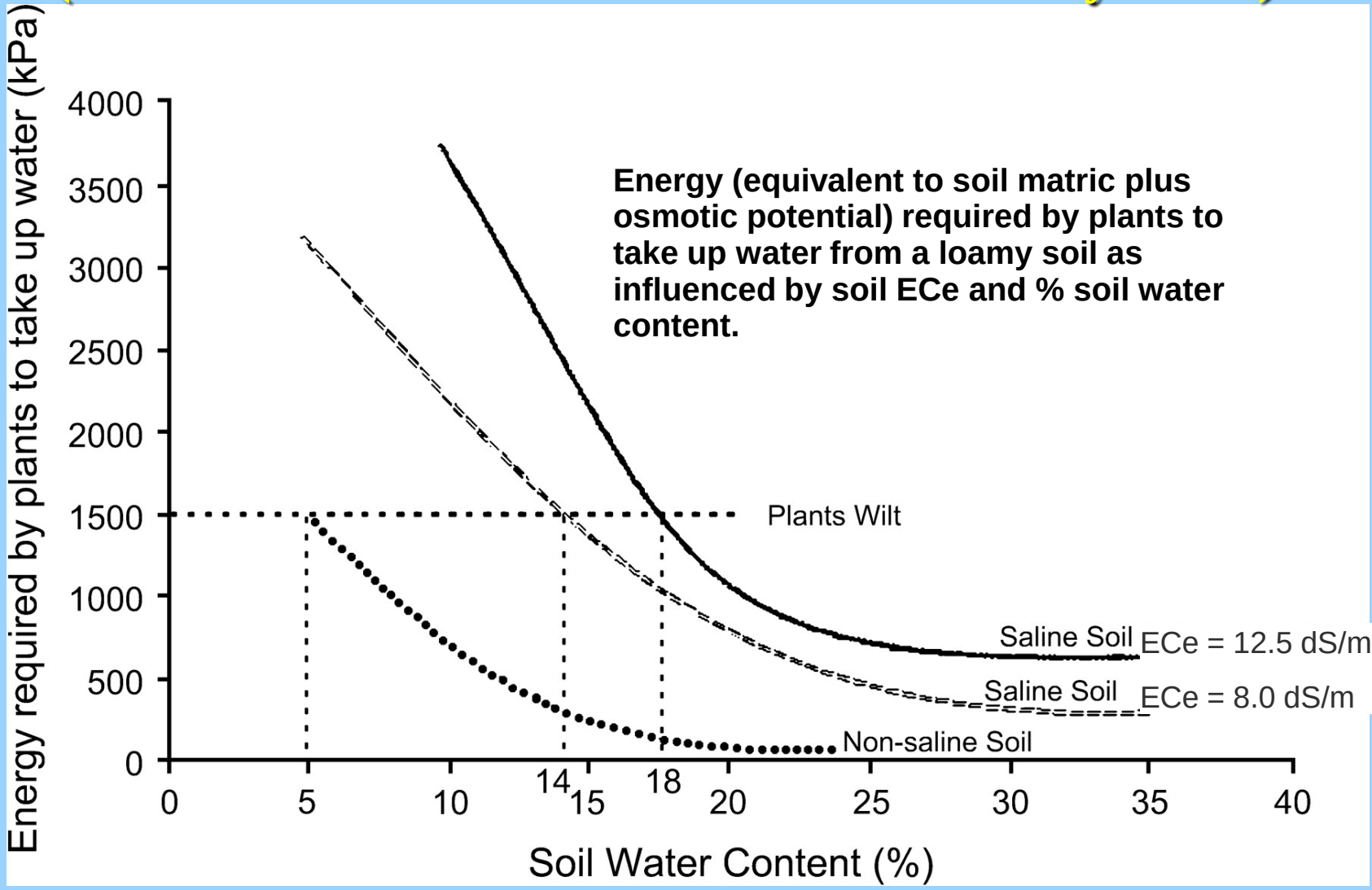
Plant stress can be high even with wet soil

(Effective soil moisture tension for a silt loam soil)



Plant stress can be high even with wet soil

(Effective total "tension" for a fine sandy loam)



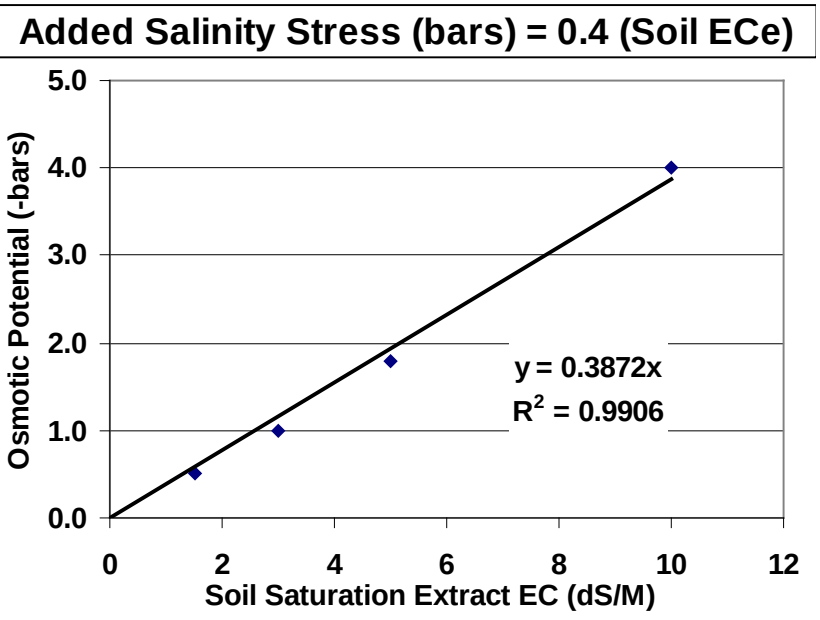
After Rengasamy P J. Exp. Bot. 2006;57:1017-1023

JOURNAL OF Experimental Botany

Ca and SO4 salts exert less osmotic stress than Na and Cl for the same EC

Osmotic Pressure for Various EC Levels of General Salt Solutions and for Specific Salt Solutions

(USDA. 1954. "Diagnosis and Improvement of Saline and Alkali Soils. Agricultural Handbook 60.)



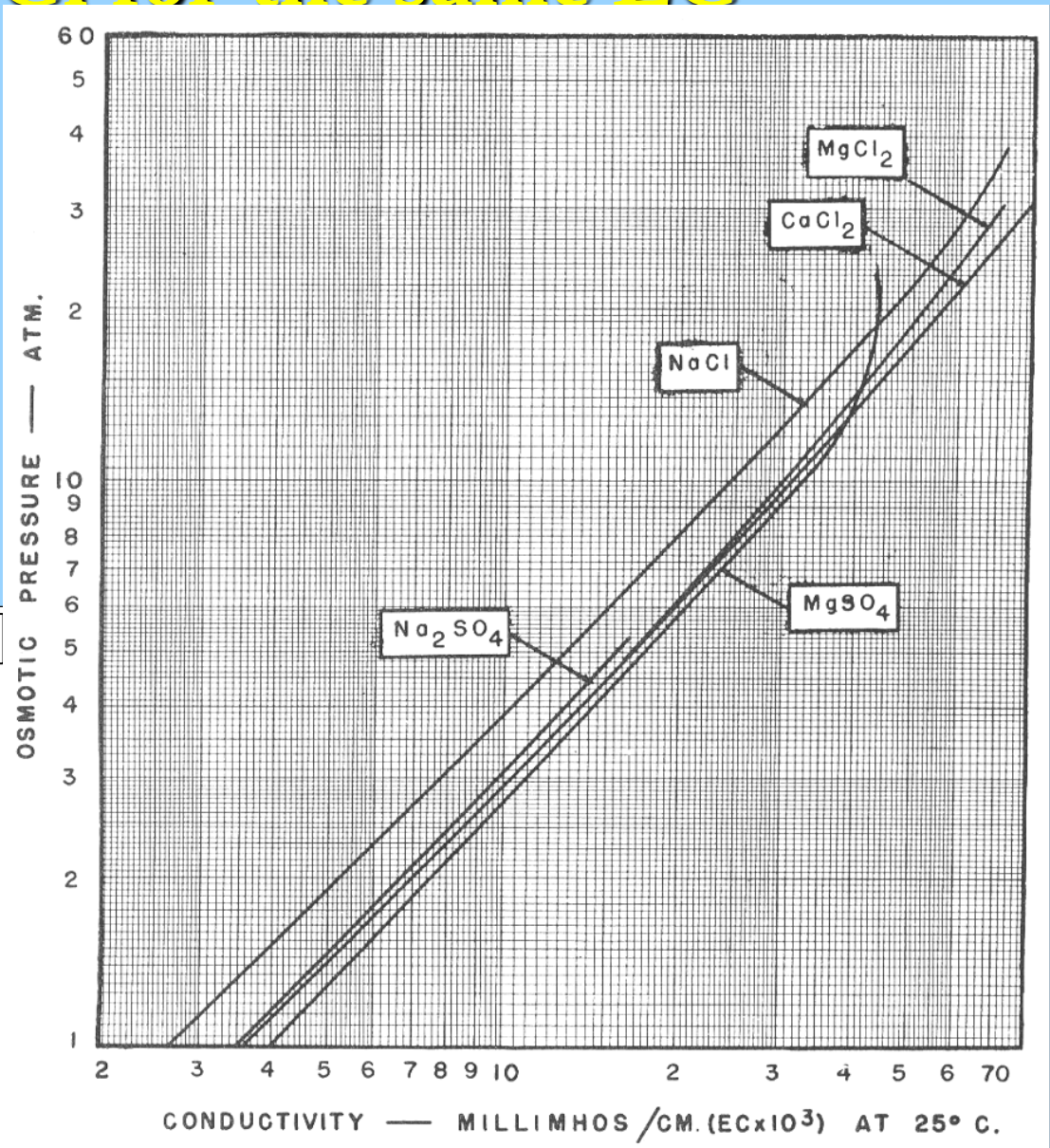
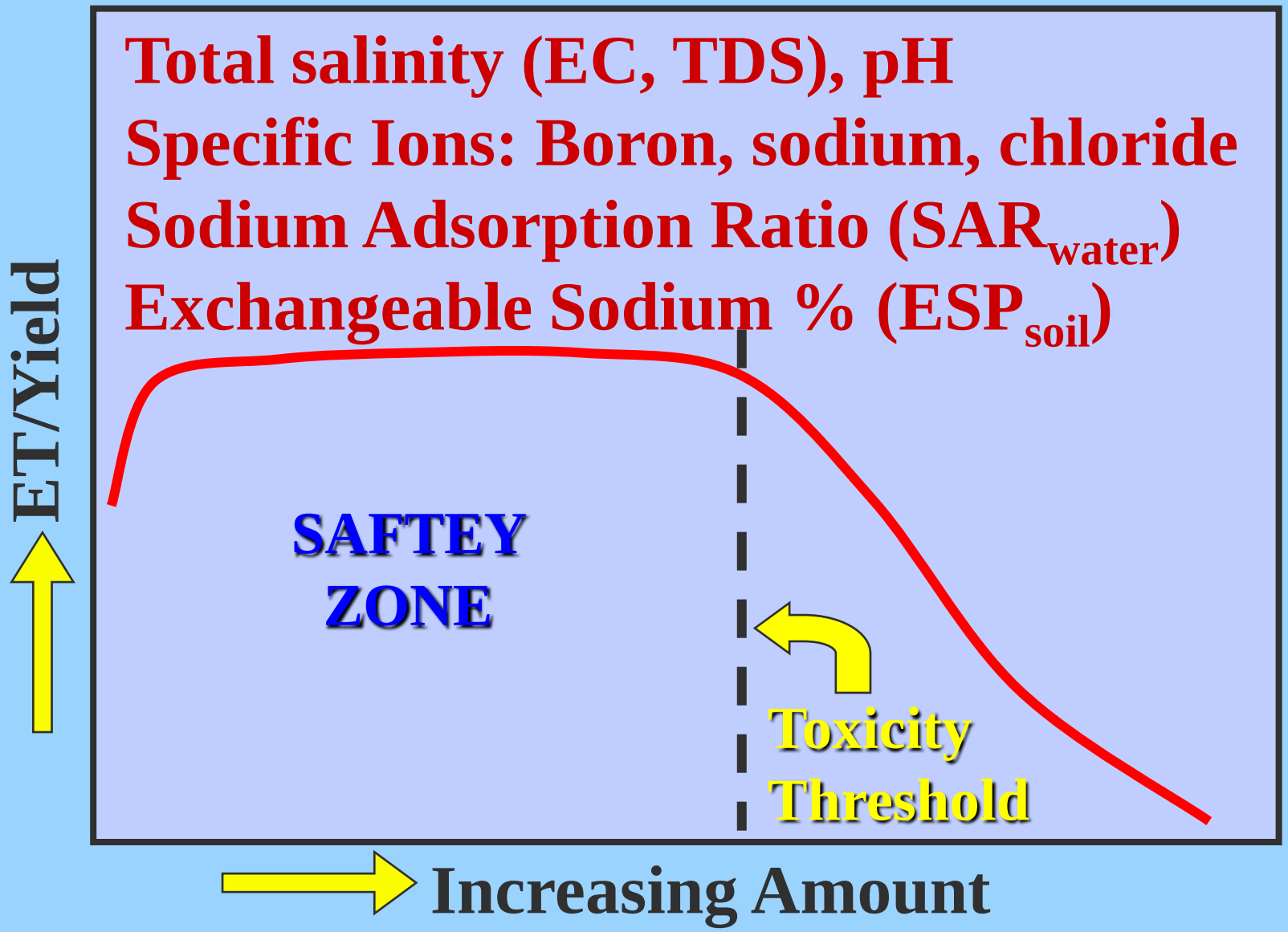


FIGURE 5.—Osmotic pressure of single-salt solutions as related to electrical conductivity. (Data from International Critical Tables.)

CLASSIC SALINITY STANDARDS

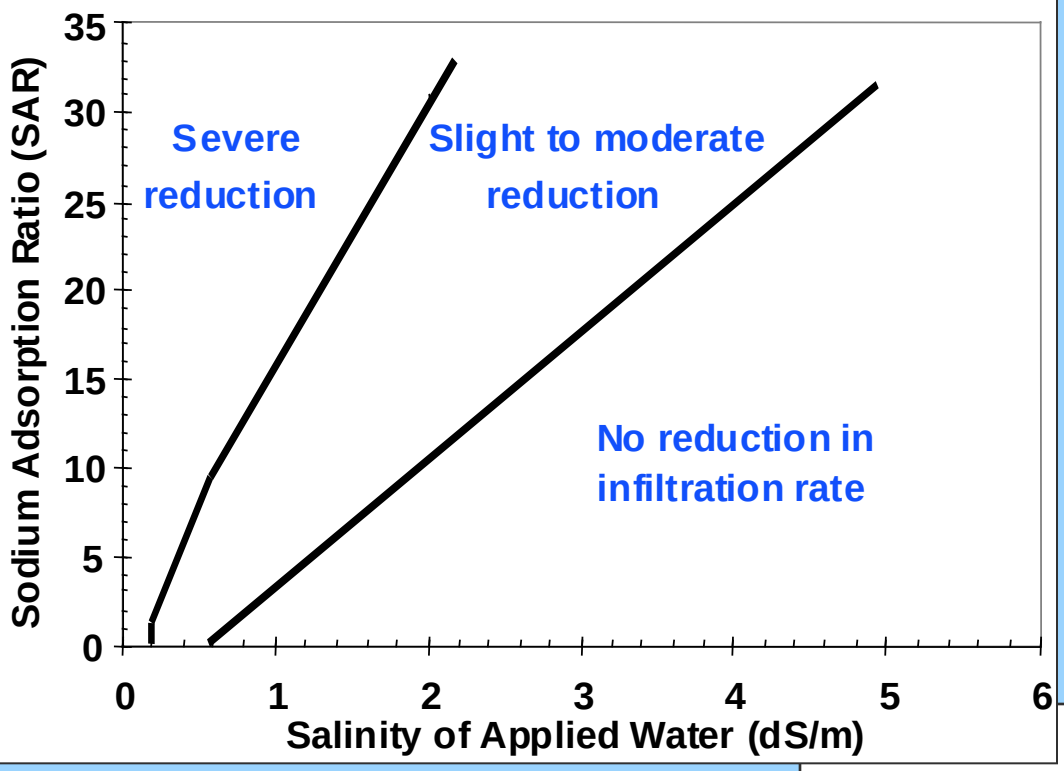
CONCEPTUAL SALINITY CONCERNS



Water Quality for Agriculture. **R.S. Ayers, D.W. Westcot. FAO Irrigation and Drainage Paper 29 Rev. 1,** Reprinted 1989, 1994
http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm

Table 1 GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION[1]

Potential Irrigation Problem		**Units**	**Degree of Restriction on Use**		
			None	**Slight to Moderate**	**Severe**
Salinity *(affects crop water availability)*					
	EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
	TDS	mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*					
Ratio of SAR/EC_w			< 5	5 – 10	> 10
Specific Ion Toxicity *(sensitive trees/vines, surface irrigation limits)*					
	Sodium (Na)[2]	meq/l	< 3	3 – 9	> 9
	Chloride (Cl)[2]	meq/l	< 4	4 – 10	> 10
	Boron (B)	mg/l	< 0.7	0.7 – 3.0	> 3.0



Infiltration Response to SAR and EC_{irr}

(Ayers, R.S. and D.W. Westcott. 1985. Water quality for agriculture. United Nations FAO Irrig & Drainage Paper No. 29, Rev.1.)

Impact of pH on micronutrient availability and emitter clogging.

HCO_3

6.5 OPTIMAL pH 7.5

- Mo deficiency
- Low Ca
- High Fe, Mn & emitter clogging

- Lime precip
- Chlorosis
- Fe, Zn, Cu, Mn deficiency

WHAT DO WE KNOW ABOUT PISTACHIOS?

Dessication and loss of photosyntheticcally active leaf area due to excess boron.

Firing of leaf margins due to sodium & chloride accumulation by harvest.

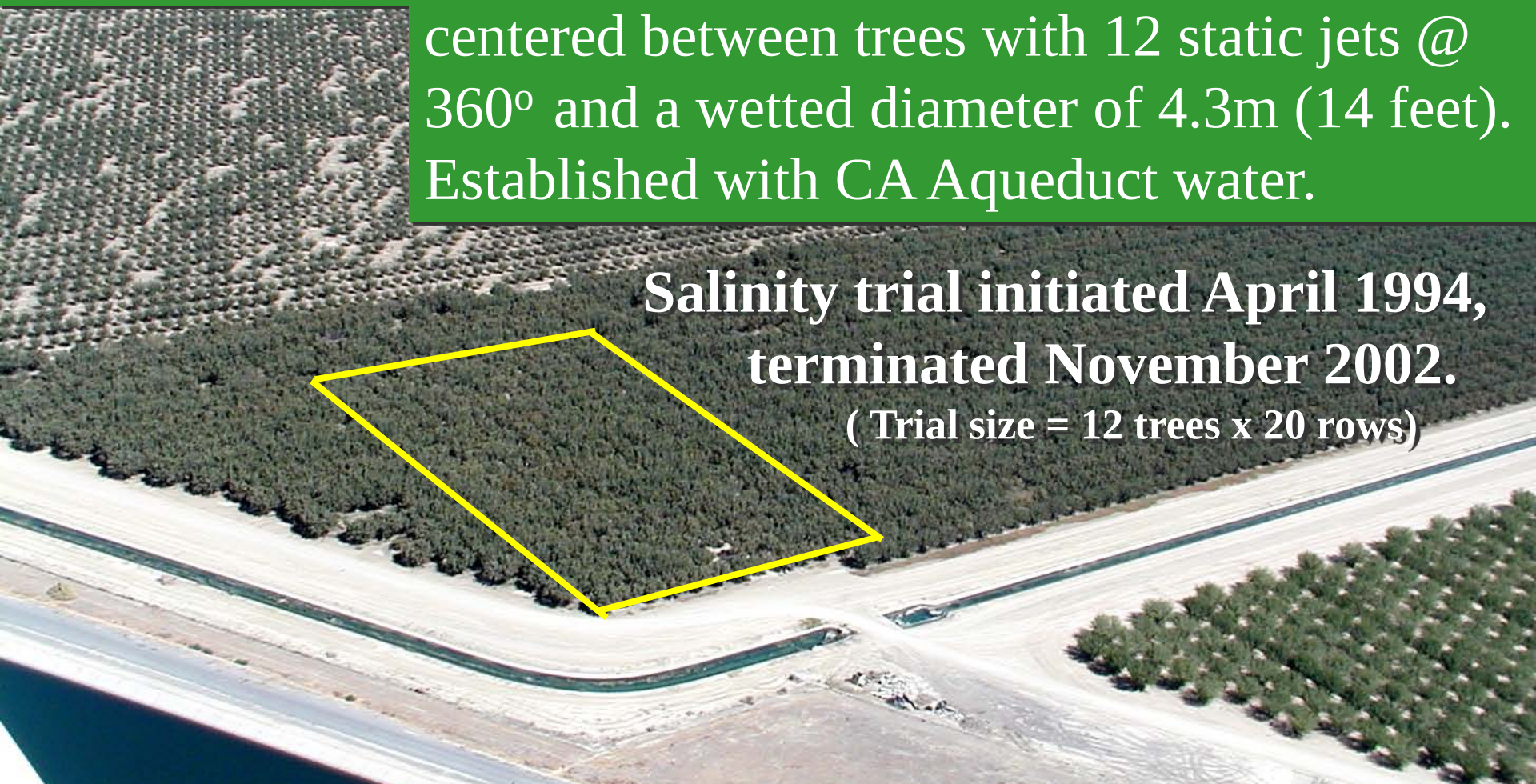
STUDY SITE – NW KERN COUNTY (Aerial 9/19/02)

40 acre pistachio orchard planted 1989

Soil: calcareous Twisselman silty clay

Spacing: 5.2 x 6.1m (17 x 20 feet)

Irrigation: One 55 lph (14.5 gph) microsprinkler/tree centered between trees with 12 static jets @ 360^{o} and a wetted diameter of 4.3m (14 feet). Established with CA Aqueduct water.



Salinity trial initiated April 1994, terminated November 2002.

(Trial size = 12 trees x 20 rows)

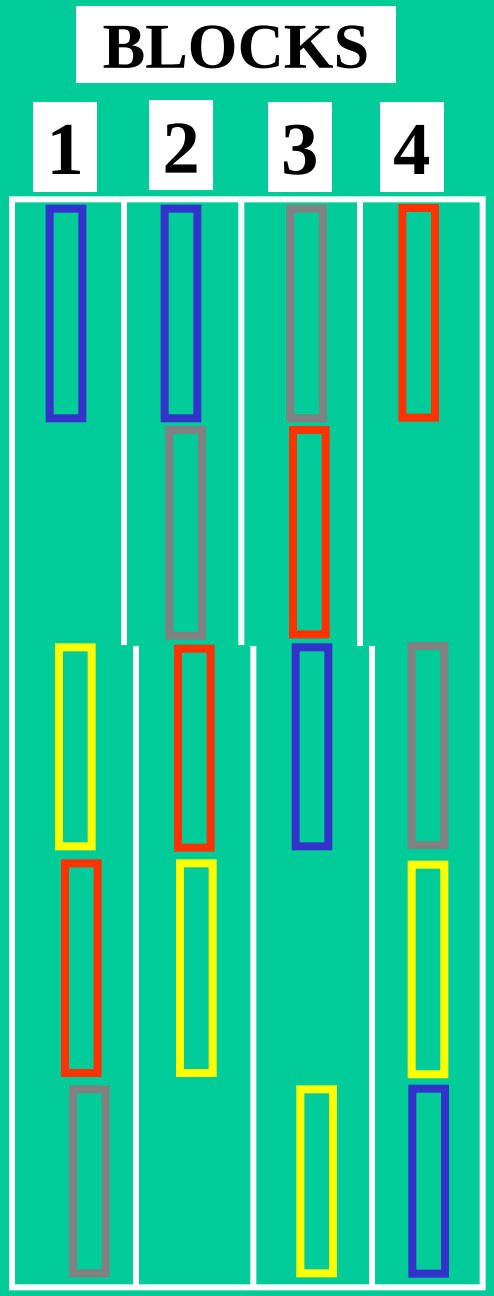
0.5-0.7 dS/m

4 dS/m

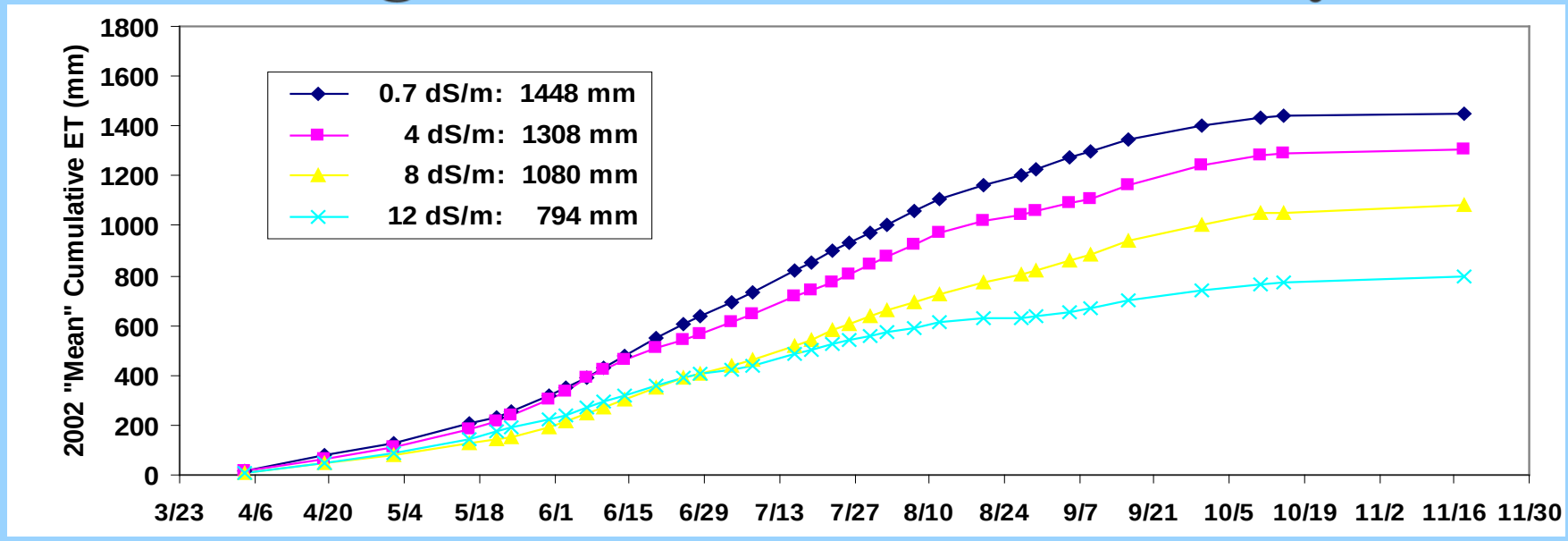
8 dS/m

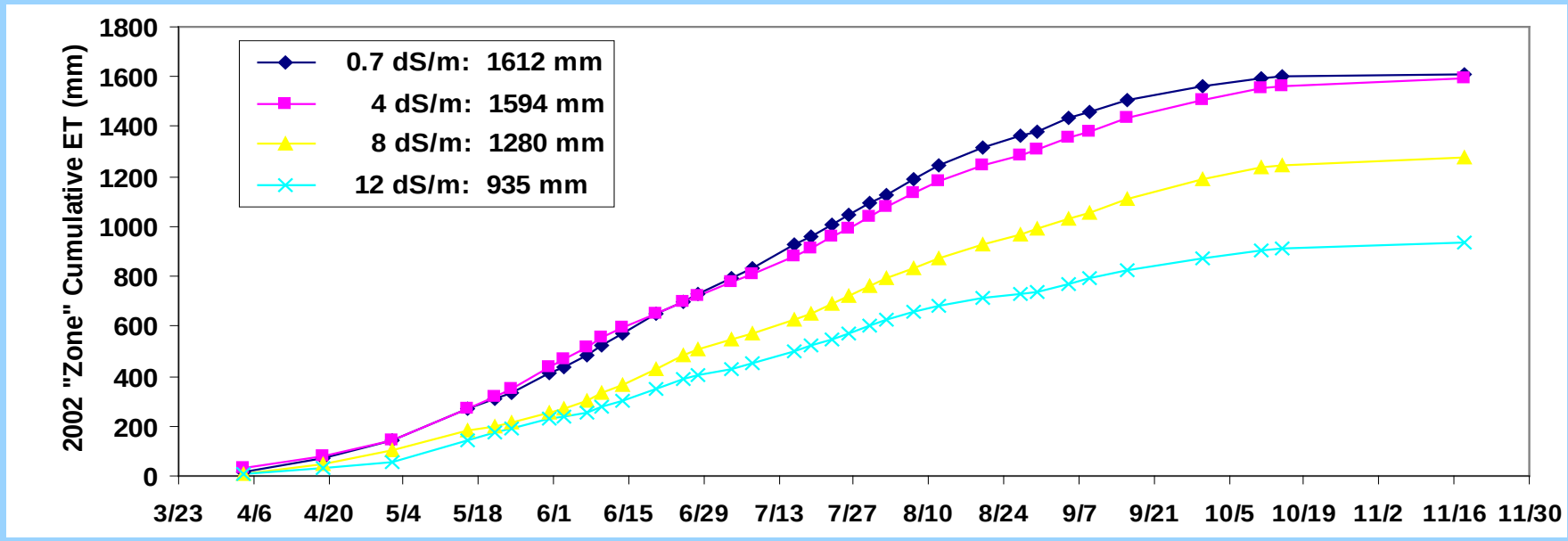
12 dS/m

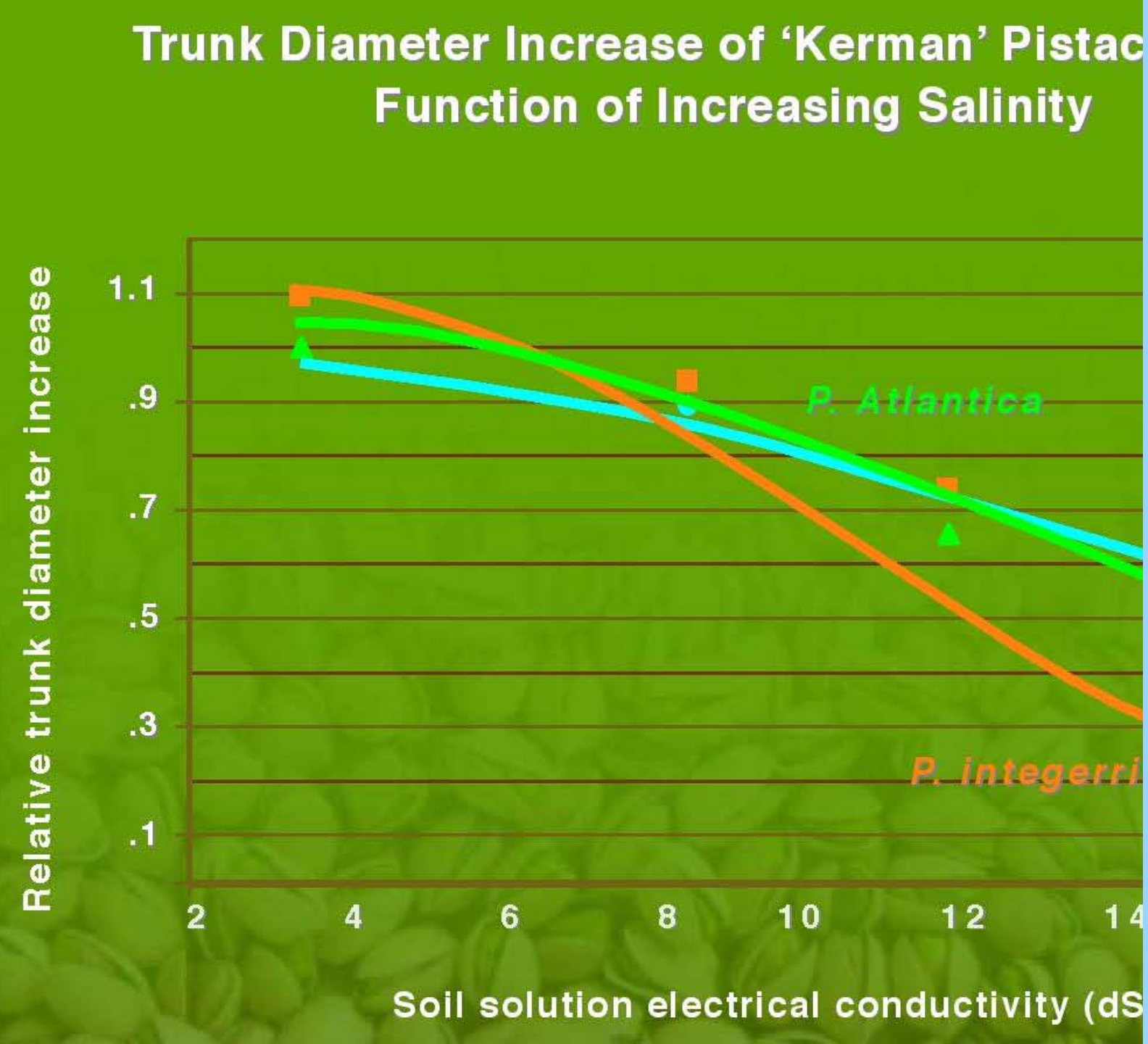
Plot Layout in Orchard



12 dS/m irrigation water decreased ET by 45%
8 dS/m irrigation water decreased ET by 25%






Trunk Diameter Increase of 'Kerman' Pistac
Function of Increasing Salinity
Relative trunk diameter increase
1.1
.9
.7
.5
.3
.1
2
4
6
8
10
12
14
P. Atlantica
P. integerri
Soil solution electrical conductivity (dS

Cumulative Yields by Salinity

Yield (kg/tree) Rootstock	Cumulative and (Average Annual) Yield per tree; 1997 - 2002 Irrigation Water / Root Zone Salinity* 0.75 / 4.7*	4.0 / 8.7*	8.0 / 11.3*	12.0+ / 13.2*	12 dS/m yield as a % of control yield
Atlantica	46.3 (7.7)	47.3 (7.8)	42.4 (7.1)	38.0 (6.3)	82%
PGI	57.3 (9.6)	52.1 (8.7)	51.6 (8.6)	51.8 (8.6)	90%
PGII	50.3 (8.4)	51.8 (8.6)	54.6 (9.1)	42.9 (7.2)	85%
UCB1	56.0 (9.3)	62.0 (10.3)	53.6 (9.4)	36.2 (6.0)	65%

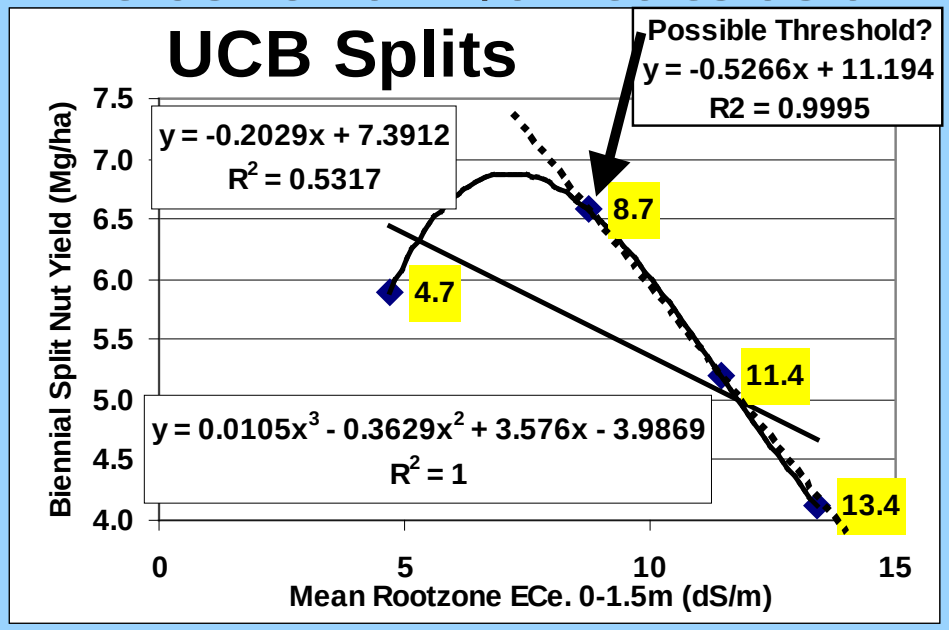
*Soil salinities are end of season 2002 values.

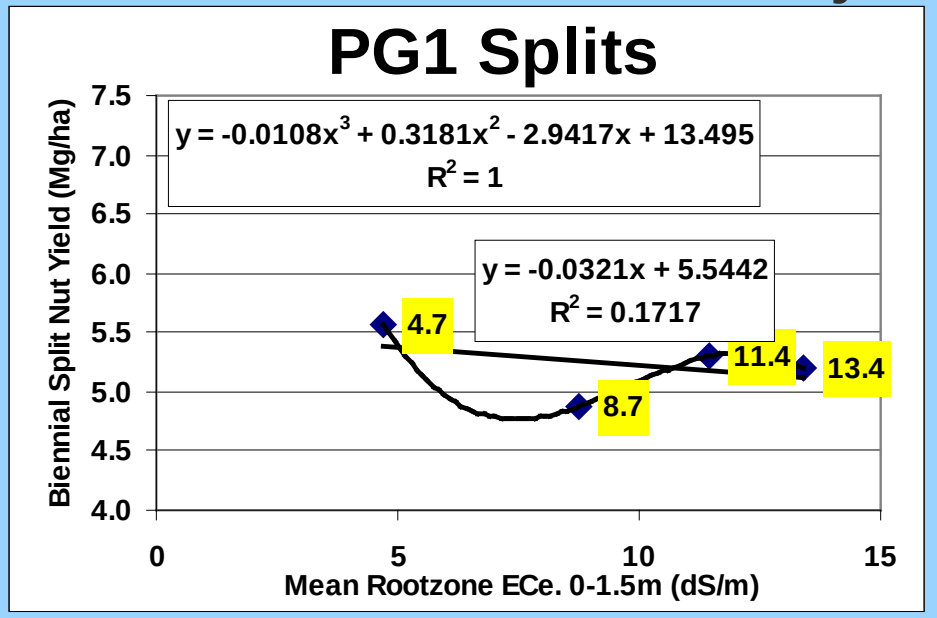
+12 dS/m irrigation was only applied for 1997 through 2002 seasons.

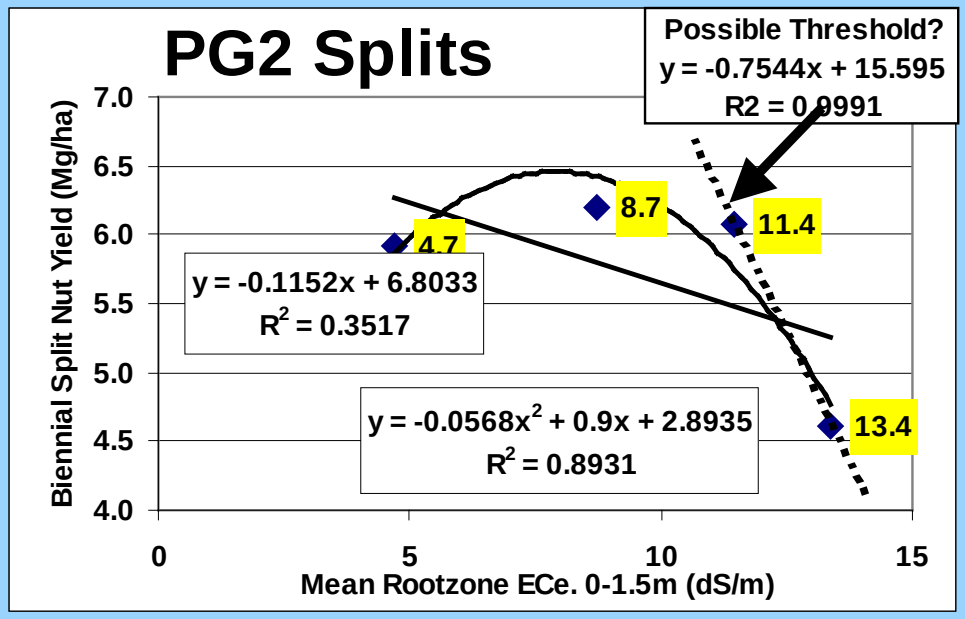
8th-13th Leaf Average Annual Yield for 0.75 to 8 dS/m water (lb/ac):

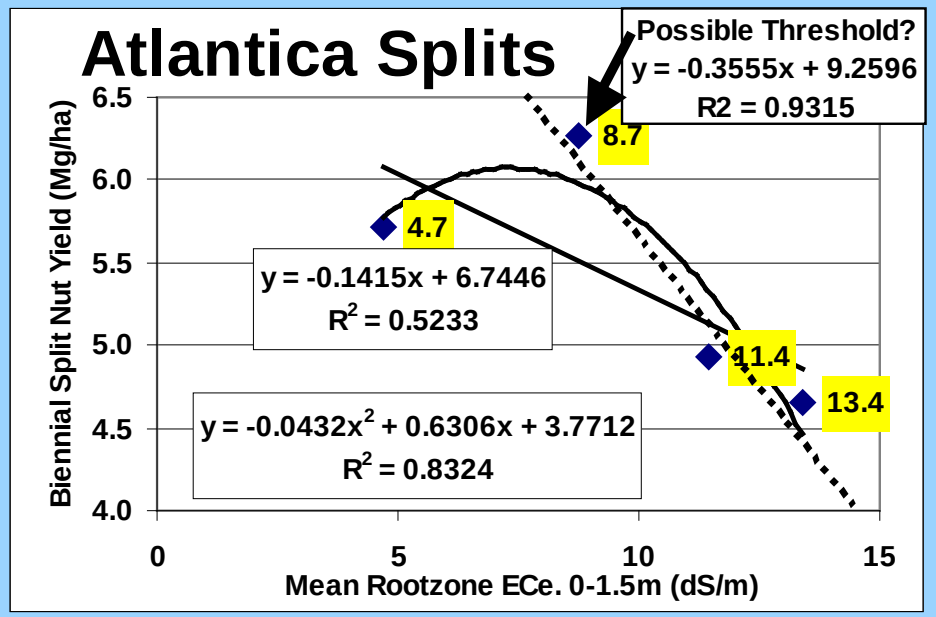
PG1	UCB1
2,531	2,727

Westside Salinity Trial 2001/2002 Biennial Split Nut Yields for all Varieties as a Function of Rootzone Salinity



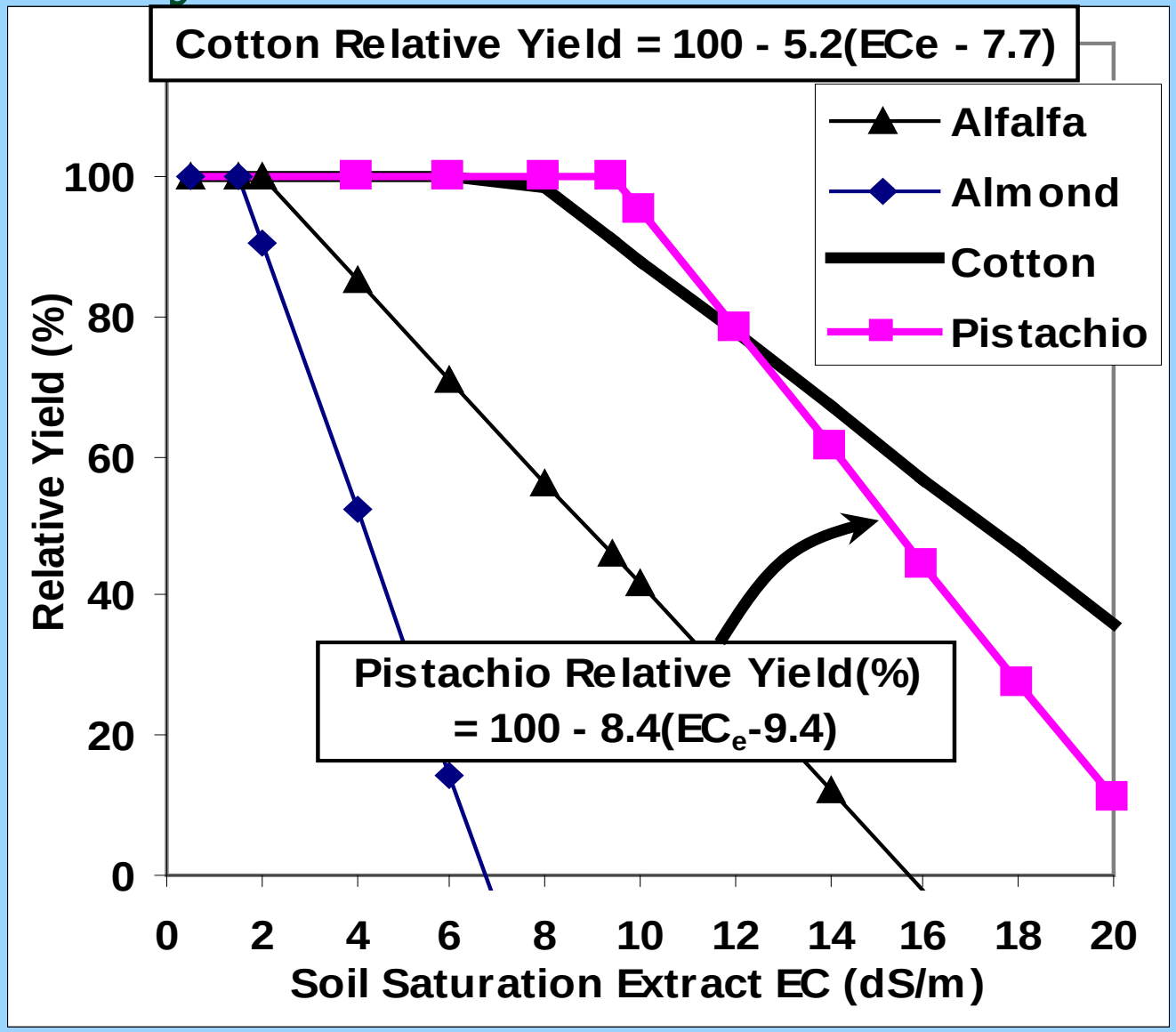






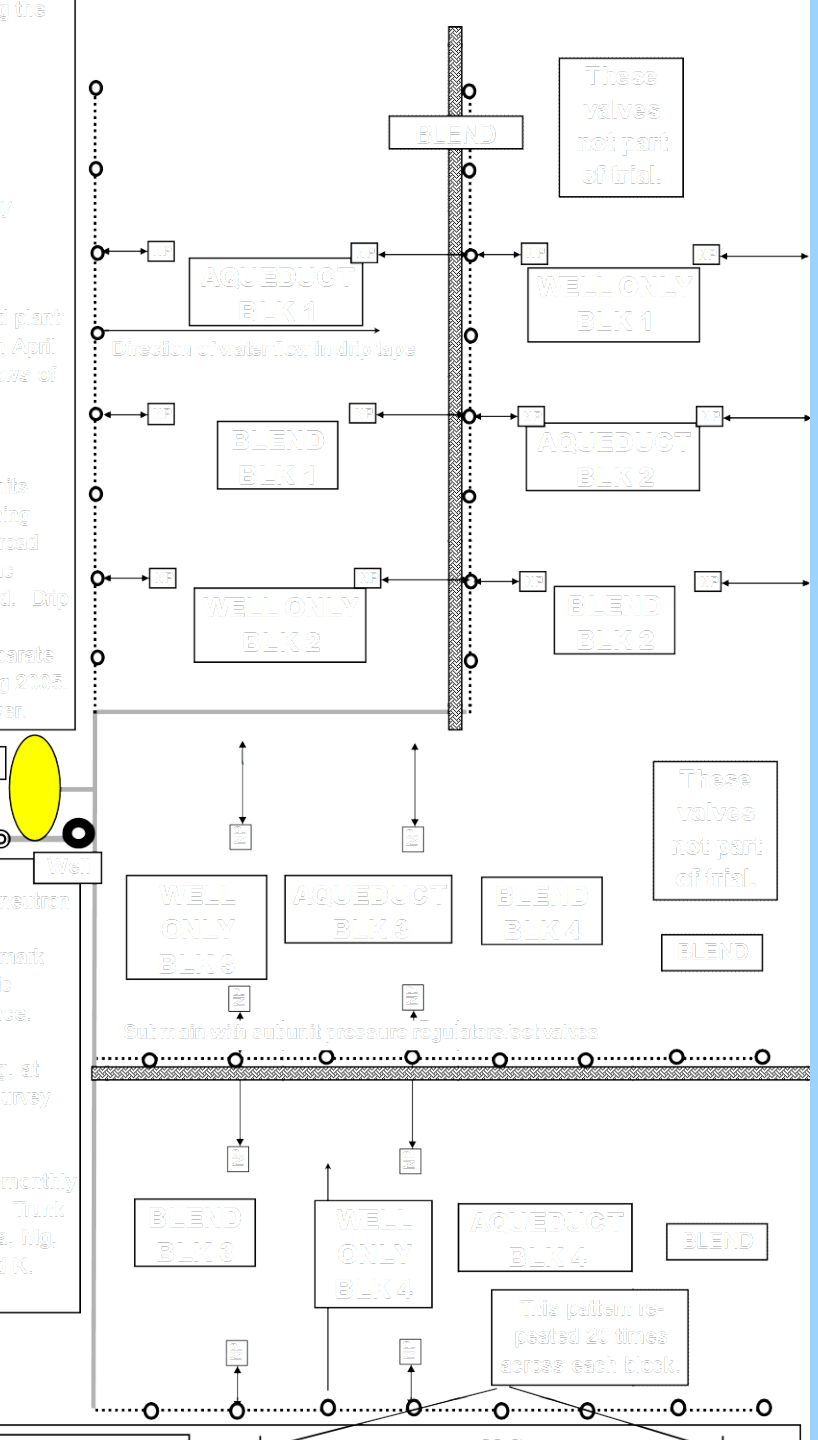
CURRENT SALINITY THRESHOLDS FOR PISTACHIO

Relative yield of as a function of soil ECe



Sanden, B.L., L. Ferguson, H.C. Reyes, and S.C. Grattan. 2004. Effect of salinity on evapotranspiration and yield of San Joaquin Valley pistachios. Proceedings of the IVth International Symposium on Irrigation of Horticultural Crops, Acta Horticulturae 664:583-589.

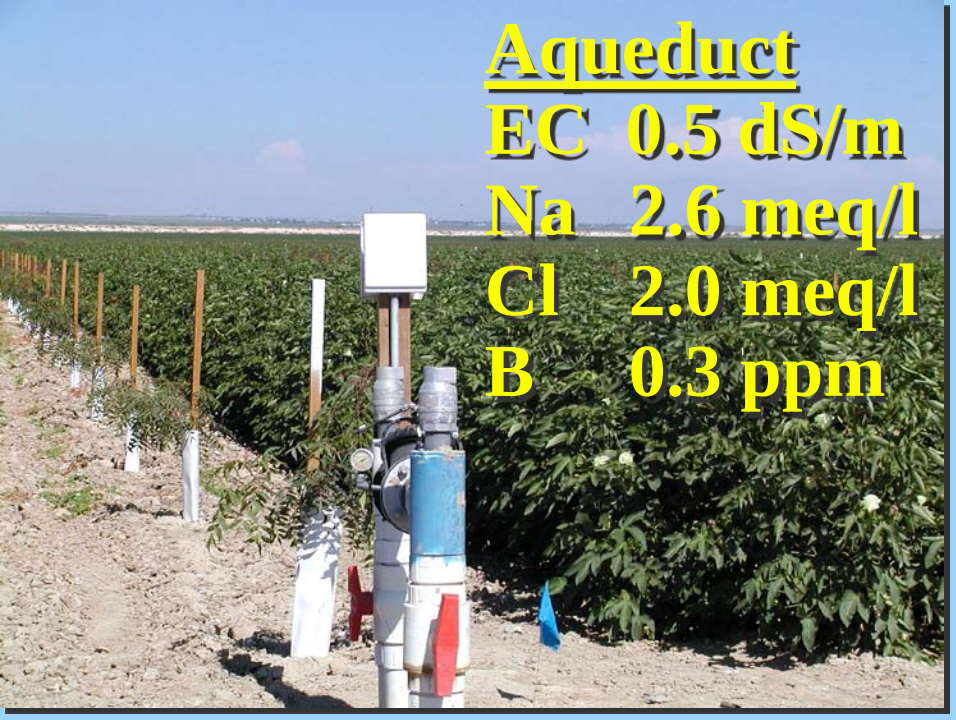
WHAT ABOUT DEVELOPING NEW PISTACHIO PLANTINGS USING SALINE WATER?



Belridge Salinity Trial

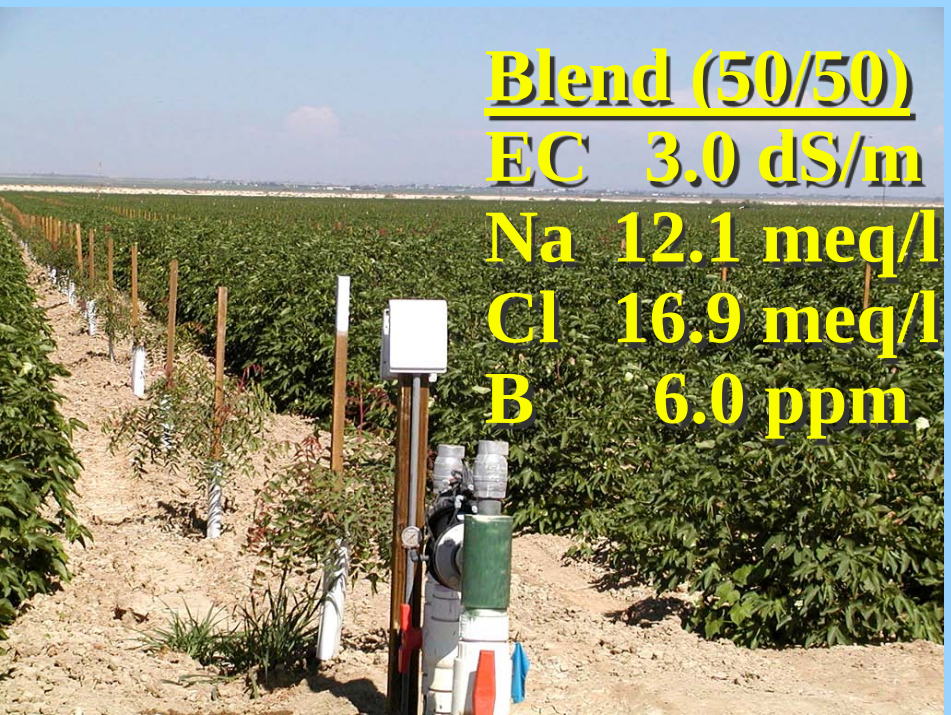
-- 2, 155 acre fields

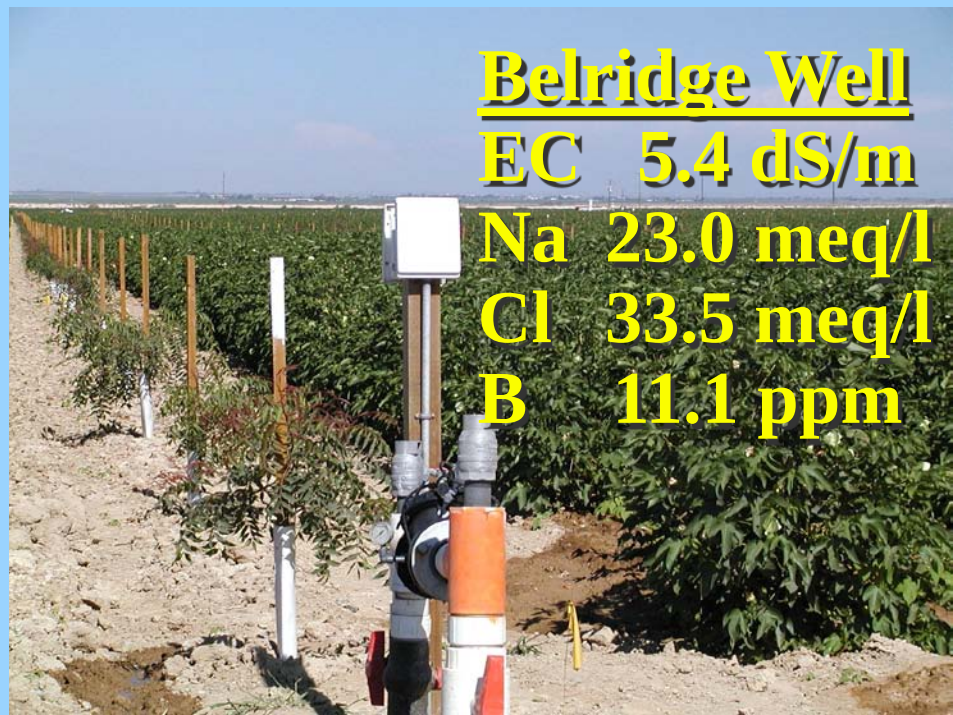
-- 12, 19.5 acre testplots



Establishing pistachios interplanted in Pima cotton using drip tape and saline water.

(1st leaf, 8/2/05)





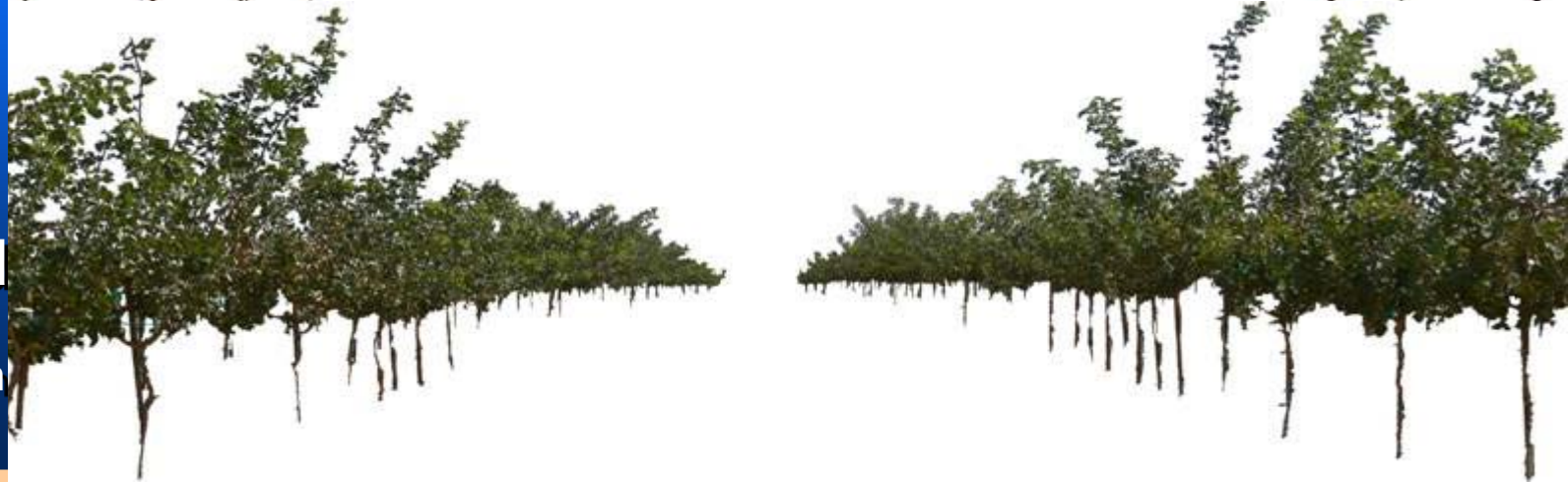
9-1 East

10/3/07 3rd Leaf

Photoshop pixel counts of pistachio foliage

V6E Well
1,156,326 pix
83.94 grn mean

V4E Aque
1,266,033 pix
81.79 grn mean



V2E Blend
1,137,636 pix
72.89 grn mean

9-1 West

9/29/10

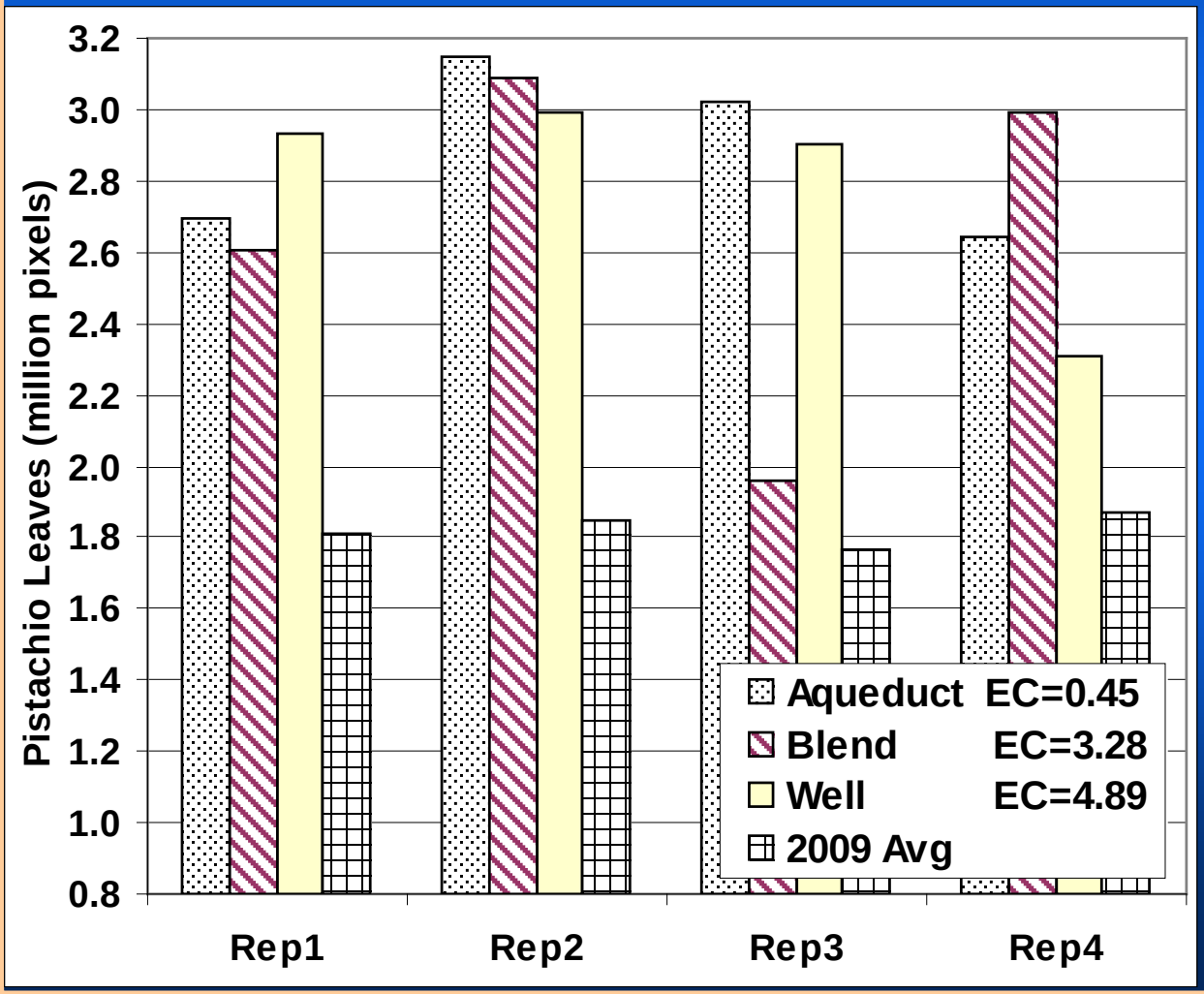
6th Leaf

V6W Aque
2,695,348 pix
83.37 grn mean

V2W Well
2,988,953 pix
81.35 grn mean

AVERAGE LEAF PIXEL TOTALS

	Leaf Pixels	% of Aque	Mean Green
AQUEDUCT	2,875,787	**100.0%**	82.70
BLEND	2,661,581	**92.6%**	83.11
WELL	2,781,567	**96.7%**	83.74



Pistachio foliage pixel counts 9/29/10

Salt added to crop rootzone from start of project

Irrigation Treatment	2004 (Cotton) Irrig (in)	2004 (Cotton) Salt (lb/ac)	2005 Irrig (in)	2005 Salt [1](lb/ac)	2006 Irrig (in)	2006 Salt (lb/ac)	2007 Irrig (in)	2007 Salt (lb/ac)	2008 Irrig (in)	2008 Salt (lb/ac)	2009 Irrig (in)	2009 Salt (lb/ac)	TOTAL Irrig (in)	TOTAL Salt (lb/ac)	[2]EC+ Max (dS/m)
Aque	32.3	2343	10.4	1742	8.3	1022	12.0	1390	8.8	1553	17.5	7022	71.7	15072	1.2
50/50	33.1	11390	10.4	8570	8.7	8994	10.8	7571	8.7	8185	15.6	14399	71.6	59109	4.6
Well	33.1	21444	11.8	14782	7.9	11104	10.7	13197	9.6	13296	16.6	18444	73.1	92267	7.2

[1]Irrigation inches for total tree spacing, salt totals (lb/ac) calculated for a 9.5 foot wide subbing area centered on the tree row. Assumes 640 ppm soluble salt = 1 dS/m and a 5 ac-ft depth of soil = 20 million lbs.

[2]Maximum increase in soil saturated paste EC for a 5 foot rootzone with no precipitation of salts and no leaching past the 5 foot depth.

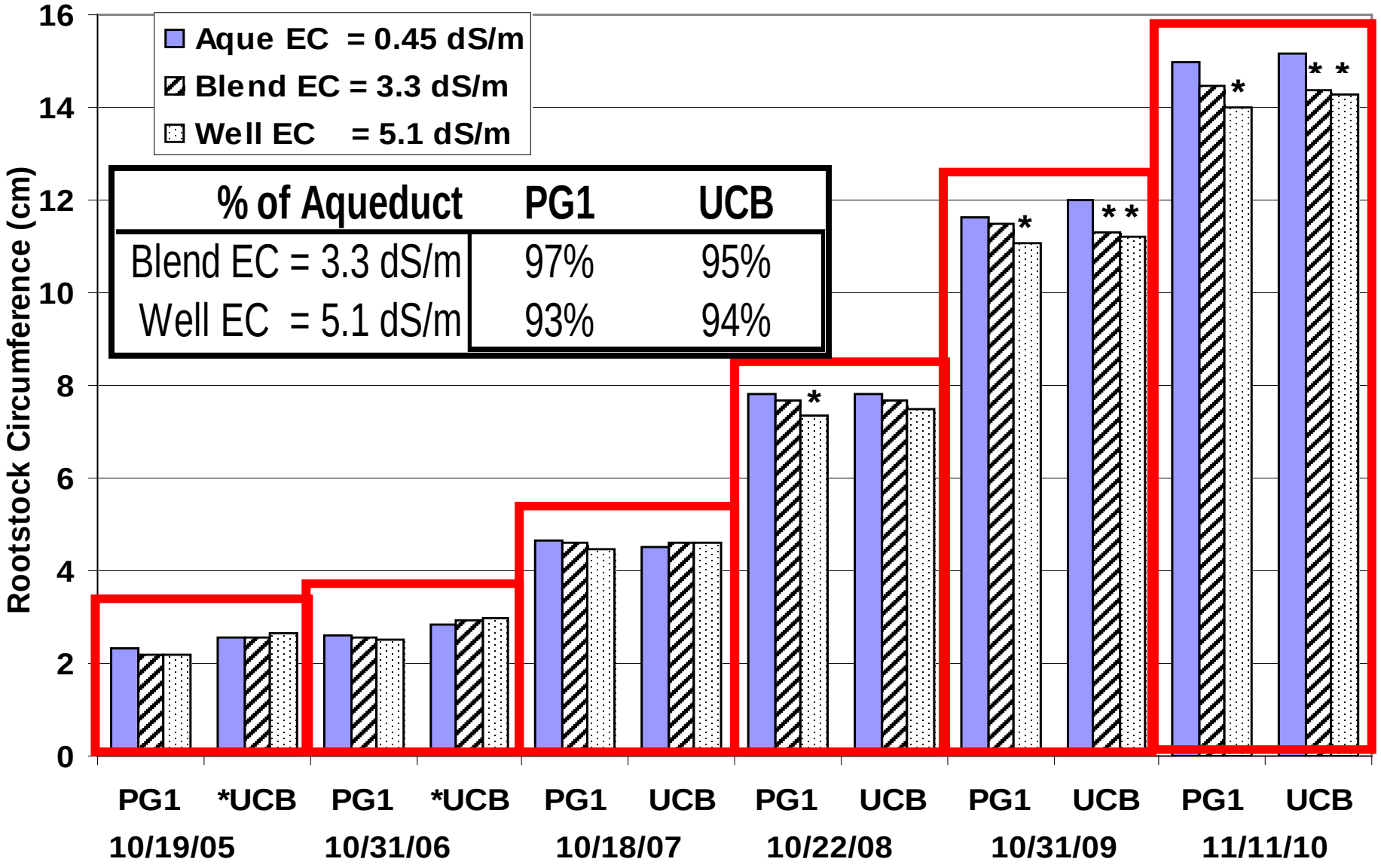
Change in tissues and soil salinity

	Kerman Leaves 10/31/06			Pistachio 2006			Rootzone ECe to 5'	Trunk Cir (in)
	N (%)	P (%)	K (%)	Na(ppm)	Cl (%)	B(ppm)	10/30/06	10/19/06
Aque	1.19	0.08	2.67	171	0.52	531	**2.65**	2.58
50/50	1.36	0.08	2.83	140	*0.58	**954	**4.34**	2.55
Well	*1.55	0.09	2.99	201	*0.62	**1096	***4.61**	2.49
	Kerman Leaves 8/26/08 (PG1)				**Pistachio 2008**		**4/25/08**	**10/22/08**
Aque	2.29	0.13	2.91	80	0.12	301	**2.60**	7.81
50/50	2.36	0.13	2.87	84	0.12	684	***4.69**	7.55
Well	2.33	0.13	3.15	79	0.15	**870	****5.64**	*7.23
	Kerman Leaves 8/26/08 (UCB1)				**Pistachio 2008**		**11/11/08**	**10/22/08**
Aque	2.32	0.13	2.41	83	0.14	269	**2.84**	7.83
50/50	2.41	0.13	*2.73	75	0.13	**606	***5.05**	7.66
Well	2.37	0.13	2.50	68	0.14	**733	****6.44**	7.49
	Kerman Leaves 7/21/10 (PG1)				**Pistachio 2010**		**7/21/10**	**11/11/10**
Aque	2.30	0.12	2.09	115	0.24	274	**5.62**	15.0
50/50	2.34	0.12	2.32	106	0.25	**563	***8.55**	14.5
Well	2.33	0.12	2.21	132	0.27	**610	***7.82**	*14.0
	Kerman Leaves 7/21/10 (UCB1)				**Pistachio 2010**			**11/11/10**
Aque	2.41	0.13	1.75	99	0.16	248		15.2
50/50	2.44	0.13	1.89	92	0.16	**479		*14.4
Well	2.53	0.13	1.84	99	0.18	**516		*14.3

*Significantly different from Aqueduct @ 0.05, **Significant @ 0.01

[1]Cotton height @ irrigation cuttoff. [2]Cotton cover = 12.7 feet/tree row Pistachio drip

2009 & ‘10 rootstock growth decreased 7% from well water



% of Aqueduct	PG1	UCB
Blend EC = 3.3 dS/m	97%	95%
Well EC = 5.1 dS/m	93%	94%

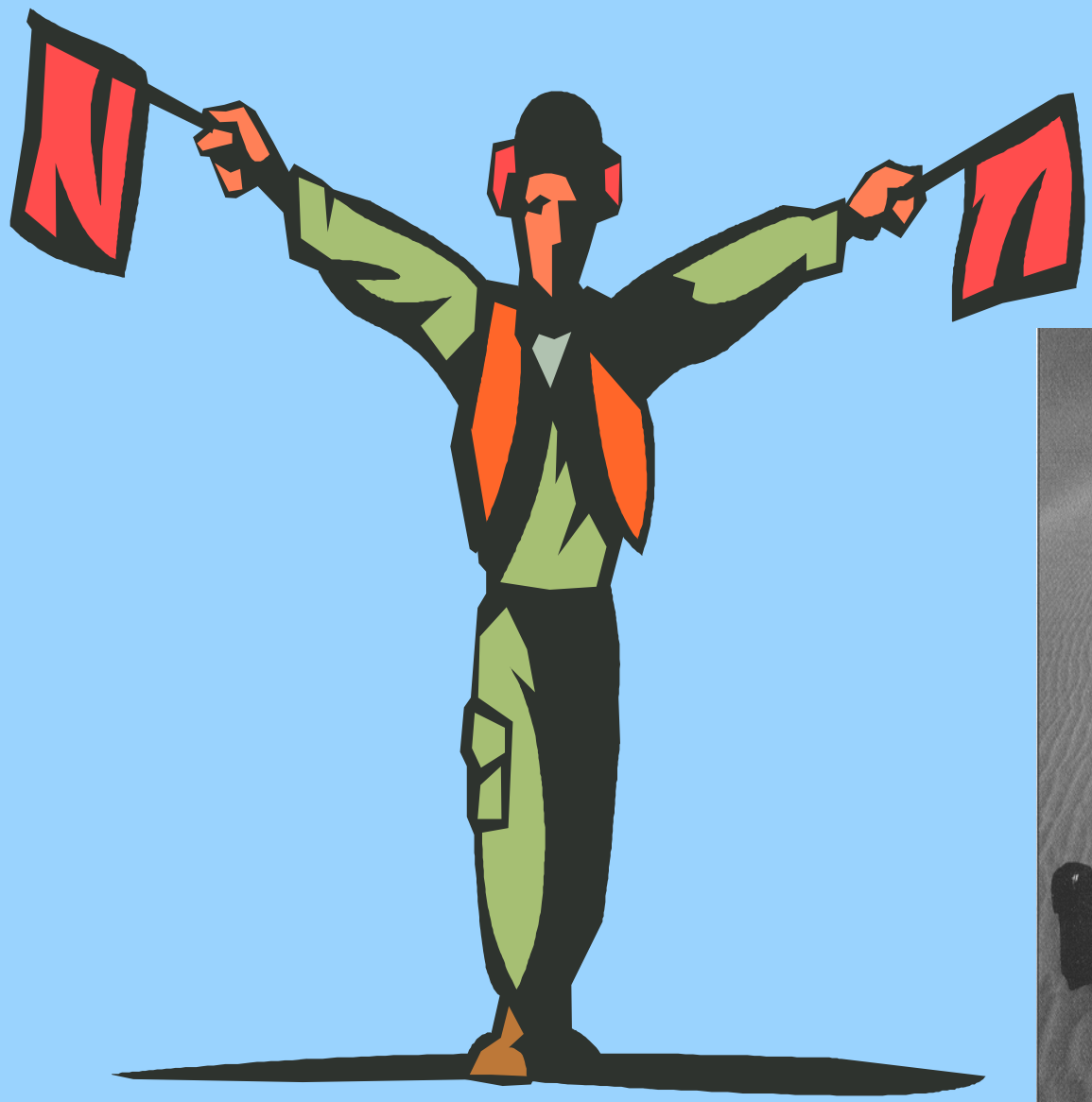
Trees planted March 5-11, 2005. Rootstock variety difference is significant for 2005 and 2006. *Irrigation salinity impact statistically significant (P<0.05)

Best current guess for soil and water toxicity thresholds for Na, Cl & B

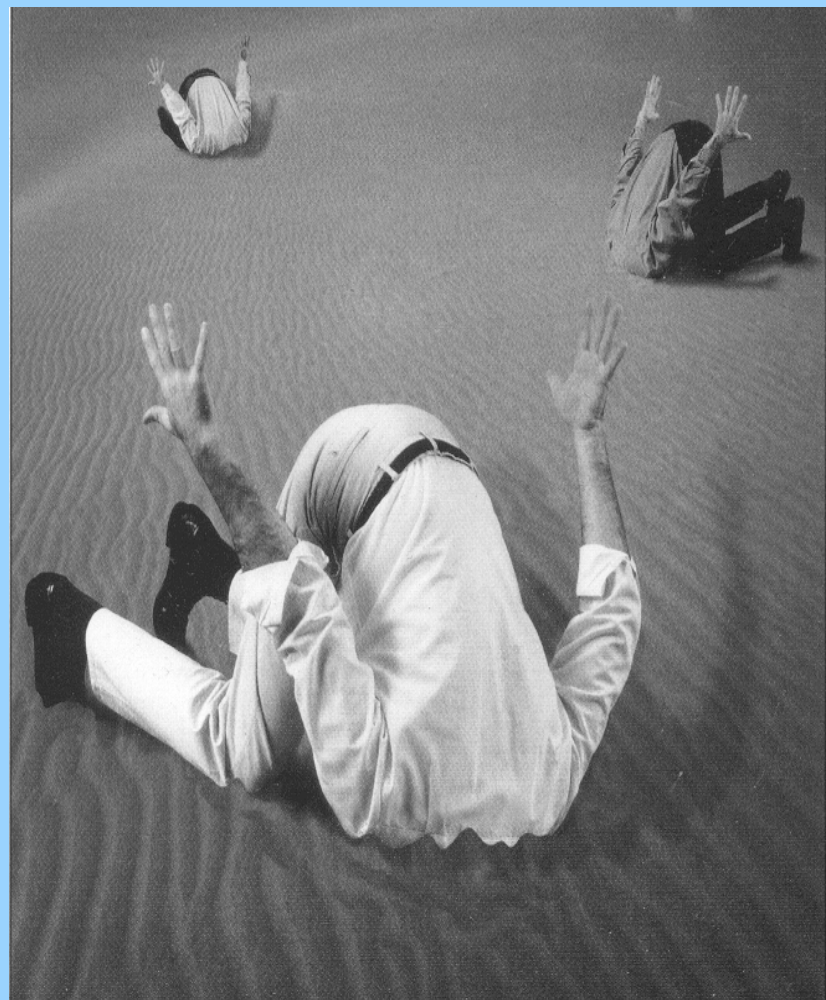
Critical levels of specific ions in irrigation water and soil saturation extract

	Degree of toxicity		
	None	Increasing	Severe
Specific ion	**Levels in Irrigation Water**		
Chloride (meq/l)	< 20	20 - 40	> 40
Boron (mg/l)	< 4	4 - 10	> 10
	Levels in Soil Saturation Extract		
Sodium (meq/l)	< 20	20 – 50	> 50
Chloride (meq/l)	< 20	20 - 40	> 40
Boron (mg/l)	< 2	2-5	> 5

Minimum leaching fractions of 10% need to be maintained at the "No toxicity" level; increasing to 40% at the "Severe" level to avoid tree defoliation.

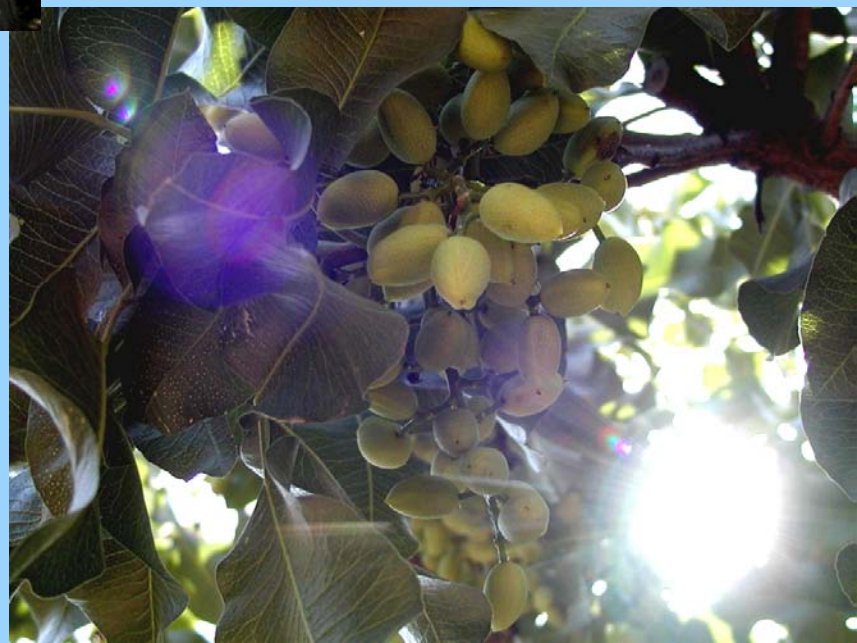


So what red flags am I looking for?



OBJECTIVES

- Tree uniformity
- Rapid maturity
- Quality/nut size
- High yield



How to do it

- **AERIAL/SATELITE PHOTOS**

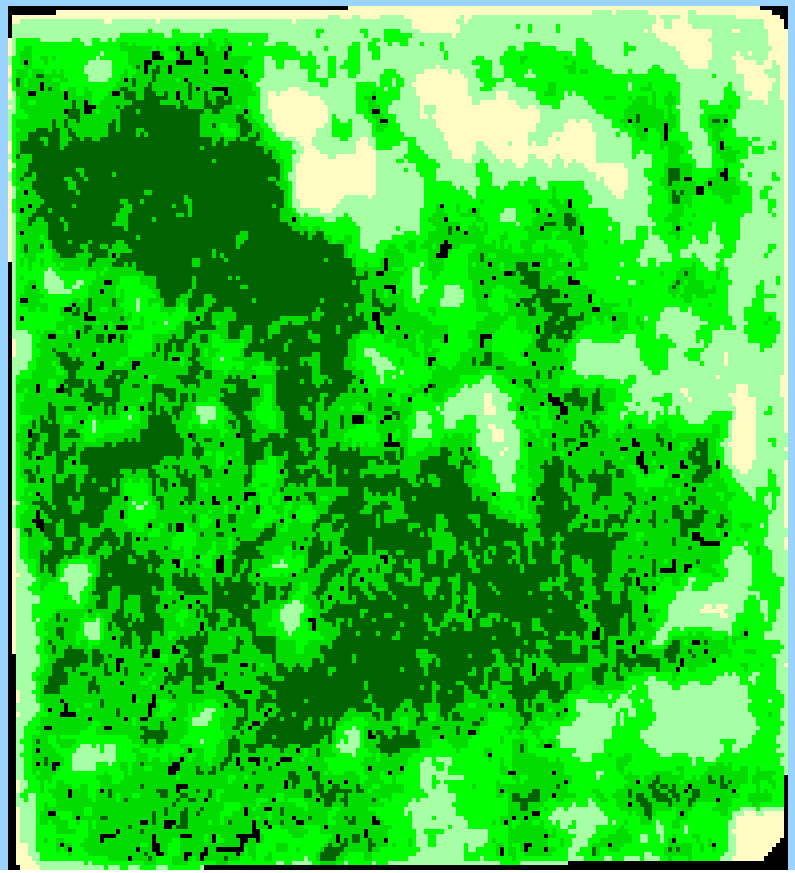
How to do it: Processed spectral imaging of forage crops identifies problem areas.

Safflower, Western Kern County 8/2/99

Near Infrared

Near Infrared Reflectance is greatest where chlorophyll content is highest

NDVI Enhanced Image



Normalized Difference Vegetation Index =

$$\frac{\text{(Near infrared reflectance – Infrared reflectance)}}{\text{(NIR + IR)}}$$

How to do it

- Are “bad” areas due to crop/water management or indicate soil salinity/textural problems?

Look for these sealing alkali "hot spots". These areas may require special attention and can't always be "fixed".

How to do it

- **Ground truth assumptions about perched water, drainage ditches, saturated soil conditions that will reduce tree performance.**

How to do it

- **SOIL PROFILE**
- **SOIL TEXTURE**

Analysis:

SP **48 -- saturation %**

pH 8.2

EC_e 6.0 dS/m

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.

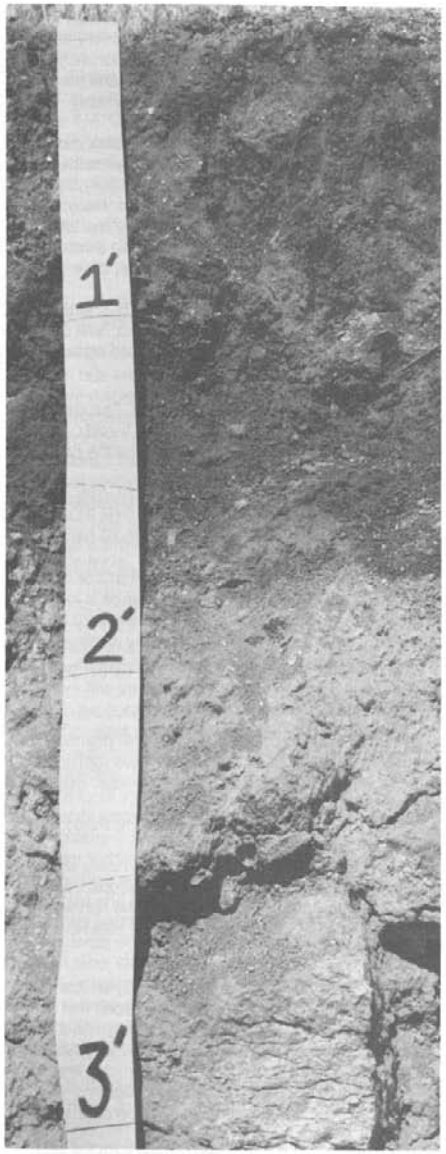
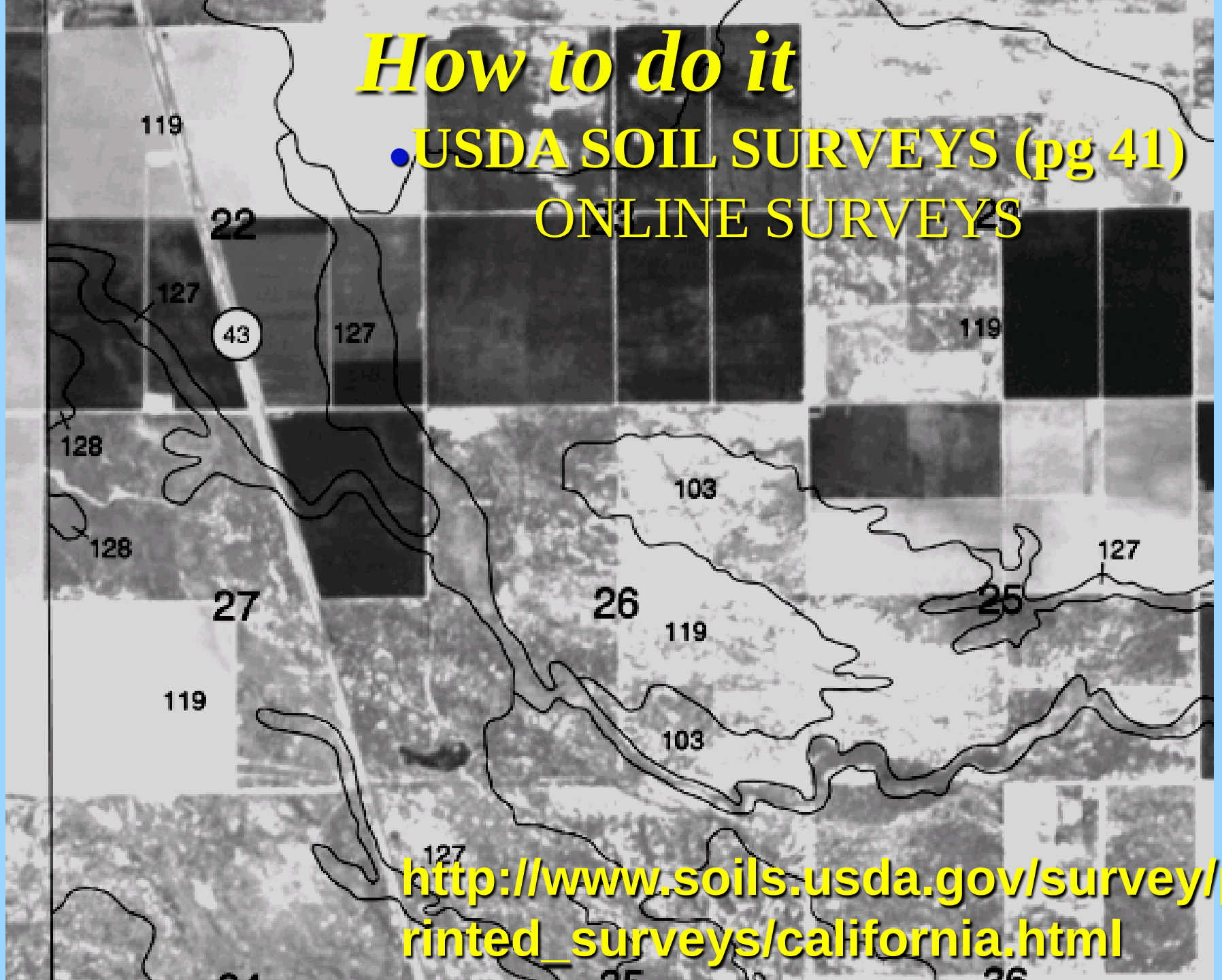


Figure 4.—Profile of Exeter sandy loam, 0 to 2 percent slopes. A duripan is at a depth of about 24 inches.



How to do it

- **USDA SOIL SURVEYS (pg 41)**

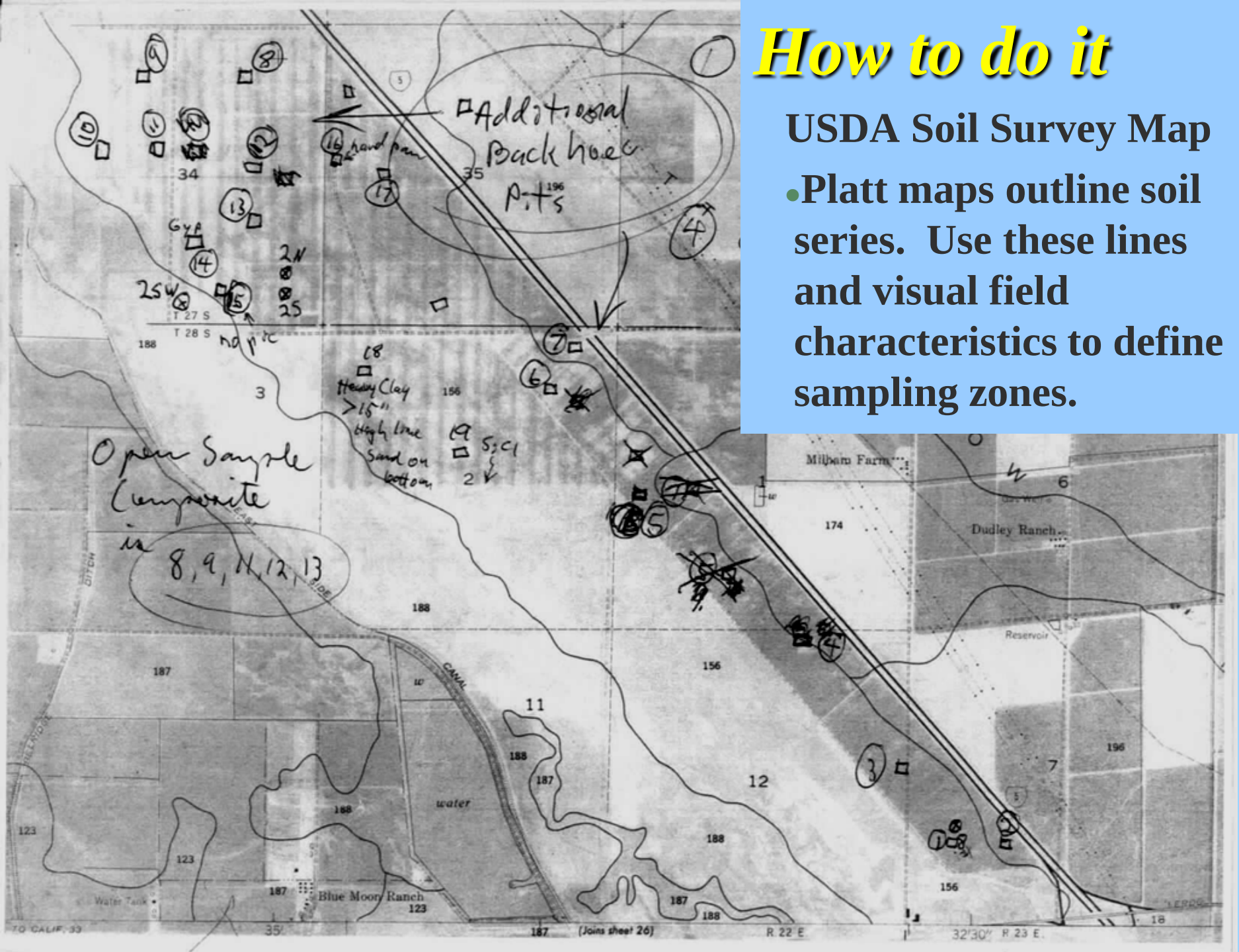
ONLINE SURVEYS

http://www.soils.usda.gov/survey/printed_surveys/california.html

How to do it

USDA Soil Survey Map

- Platt maps outline soil series. Use these lines and visual field characteristics to define sampling zones.

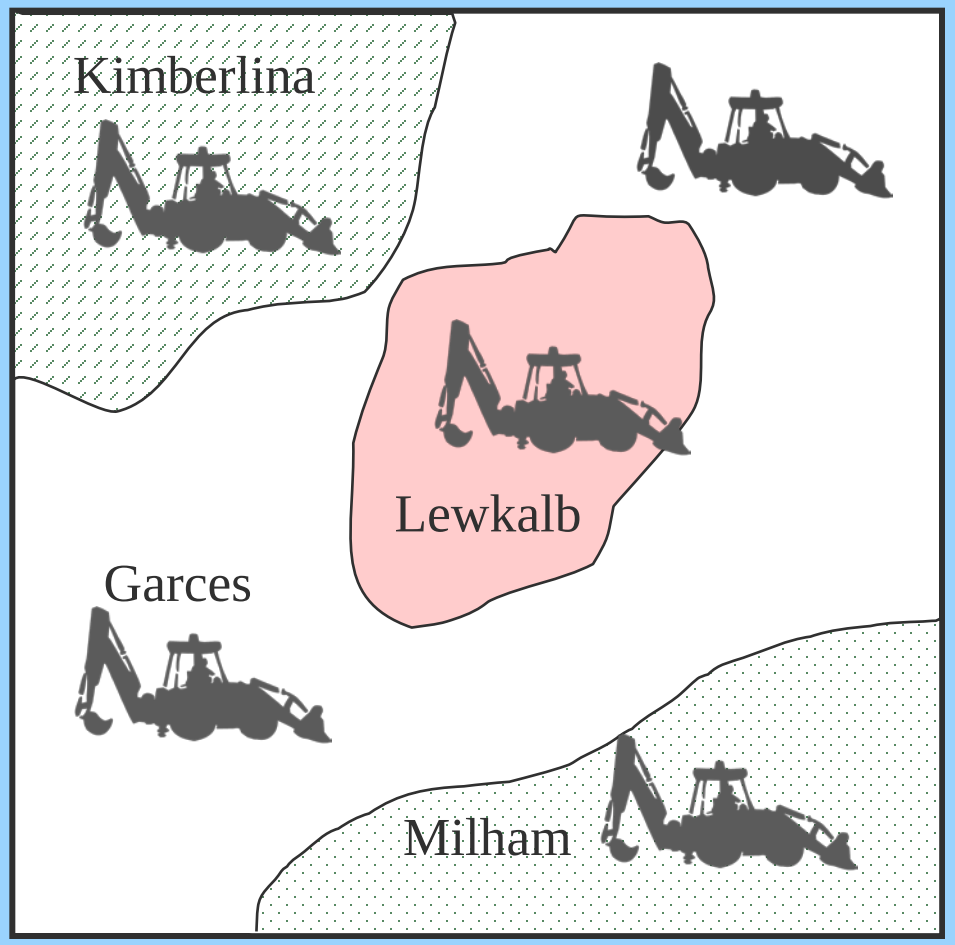


How to do it (pg 41)

- **SOIL PROFILE**
- **SOIL TEXTURE -- Sampling scheme for variable 160 acres**

- **Use soil probe or auger to composite sample 0-1 & 1-2 foot depths from at least 8 holes 50 feet apart for each soil type.**

- **Put at least one backhoe pit to 6 feet in each 40 acres of one soil type. Take deeper samples from pits.**

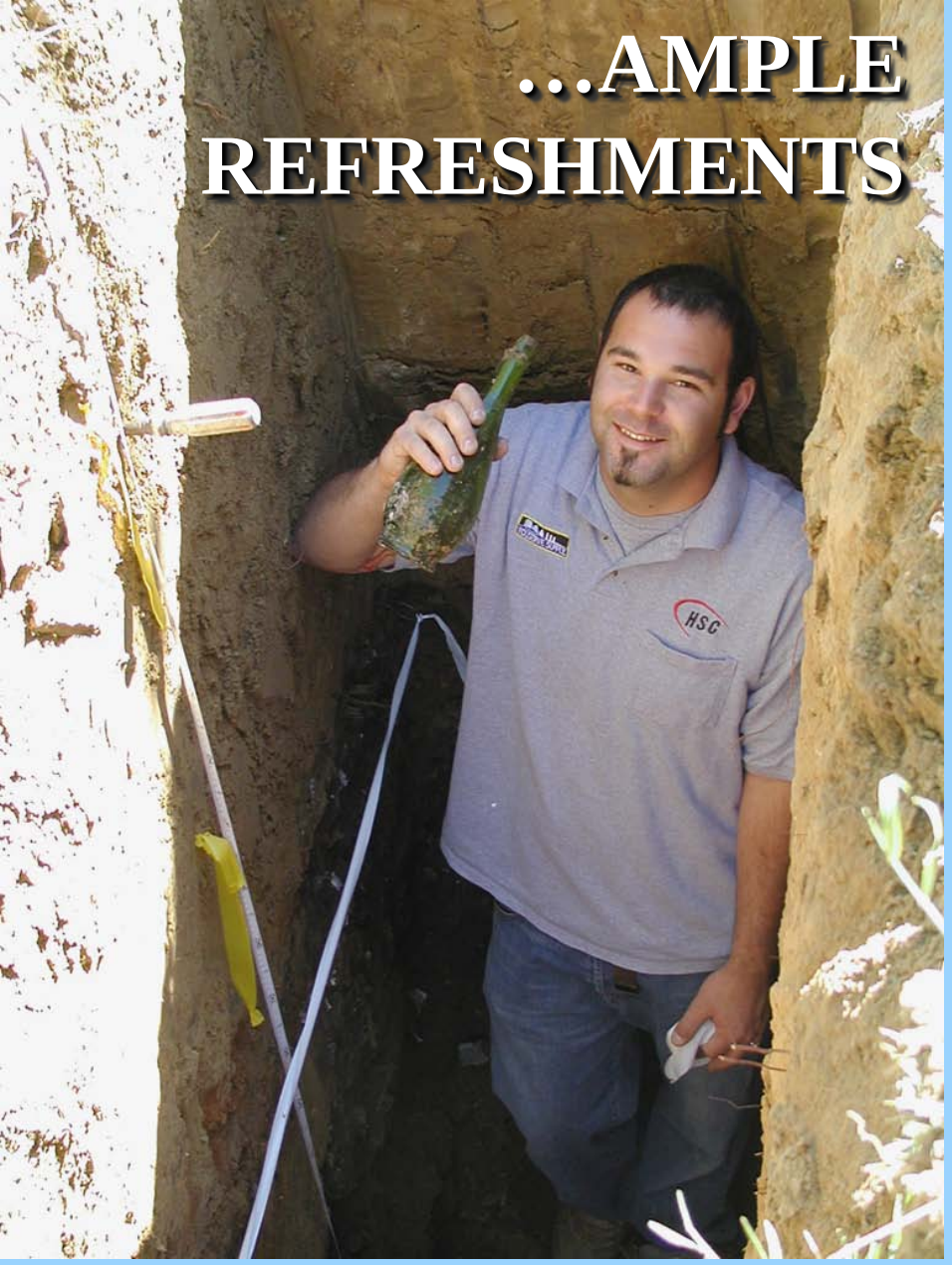


New pistachio developments in the ancient Buena Vista Lake bottom

SOIL PROFILE

- BACKHOE PITS
  - SHOVEL
  - GEOLOGIST HAMMER/PICK
  - MEASURING TAPE
  - CLIPBOARD
  - BUCKETS/BAGS
  - ….

…AMPLE REFRESHMENTS



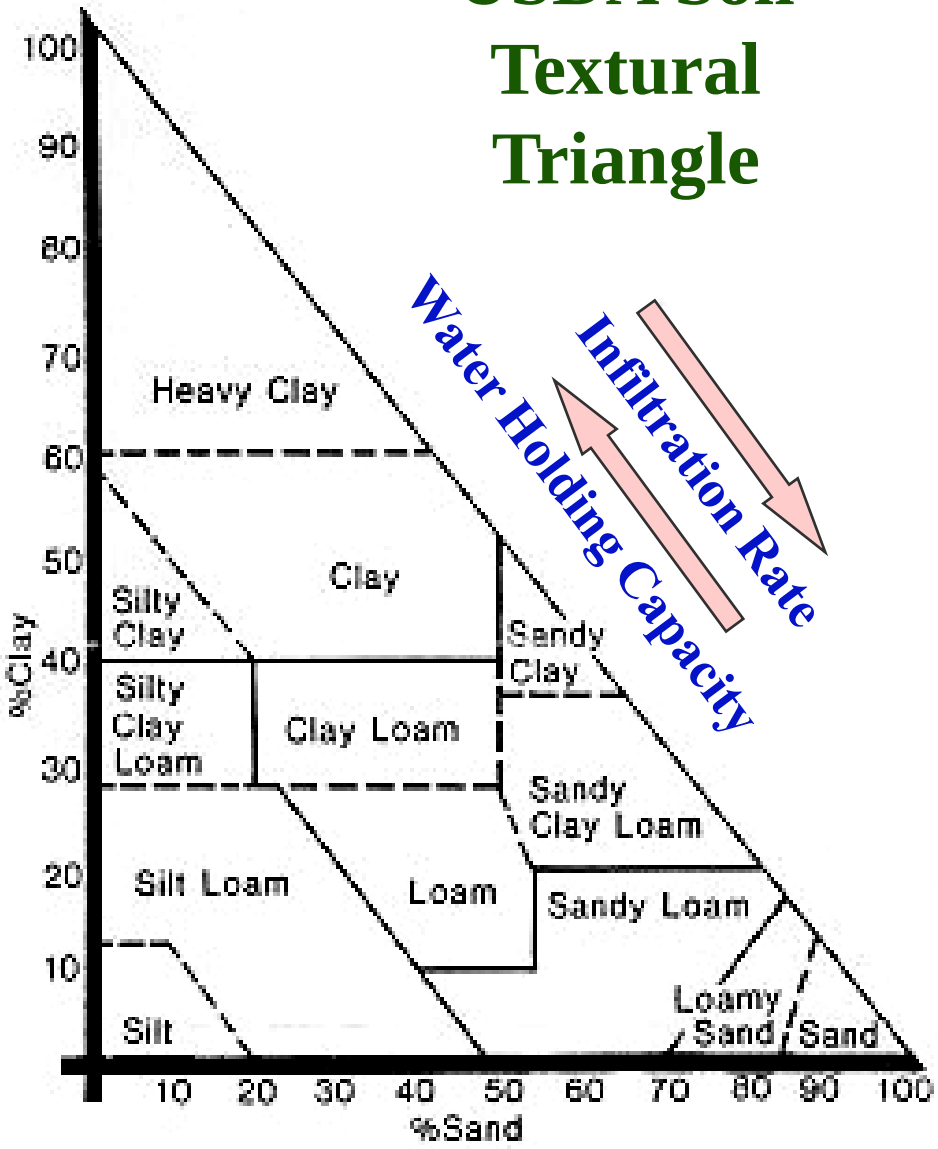

How to do it
COLLECTING SAMPLES @ DEPTH IN SOIL PITS

What to evaluate?

- **SOIL QUALITY**

- **TEXTURE**
- **STRUCTURE**
- **PERMEABILITY**
- **STRATIFICATION**
- **DRAINAGE**
- **SALINITY/Fertility**

USDA Soil Textural Triangle



How to do it

- **SOIL TEXTURE**

Making a soil "ribbon" test from a moistened ball. Sandy Clay Loam – Westside Kern County

Look for coarse soil layers below fine textures as well as hardpans and cemented layers that can impede root development and drainage.

Fine sandy silt layer with high alkalinity and poor structure at the 34 to 42 inch depth may impede root development between 2 layers of Buttonwillow/Garces clay loam. Slip plowing below this depth advisable.

What to evaluate?

Depth to perched water and localized salinity

Some spots are just too hot!

What to evaluate?

Depth to perched water and localized salinity

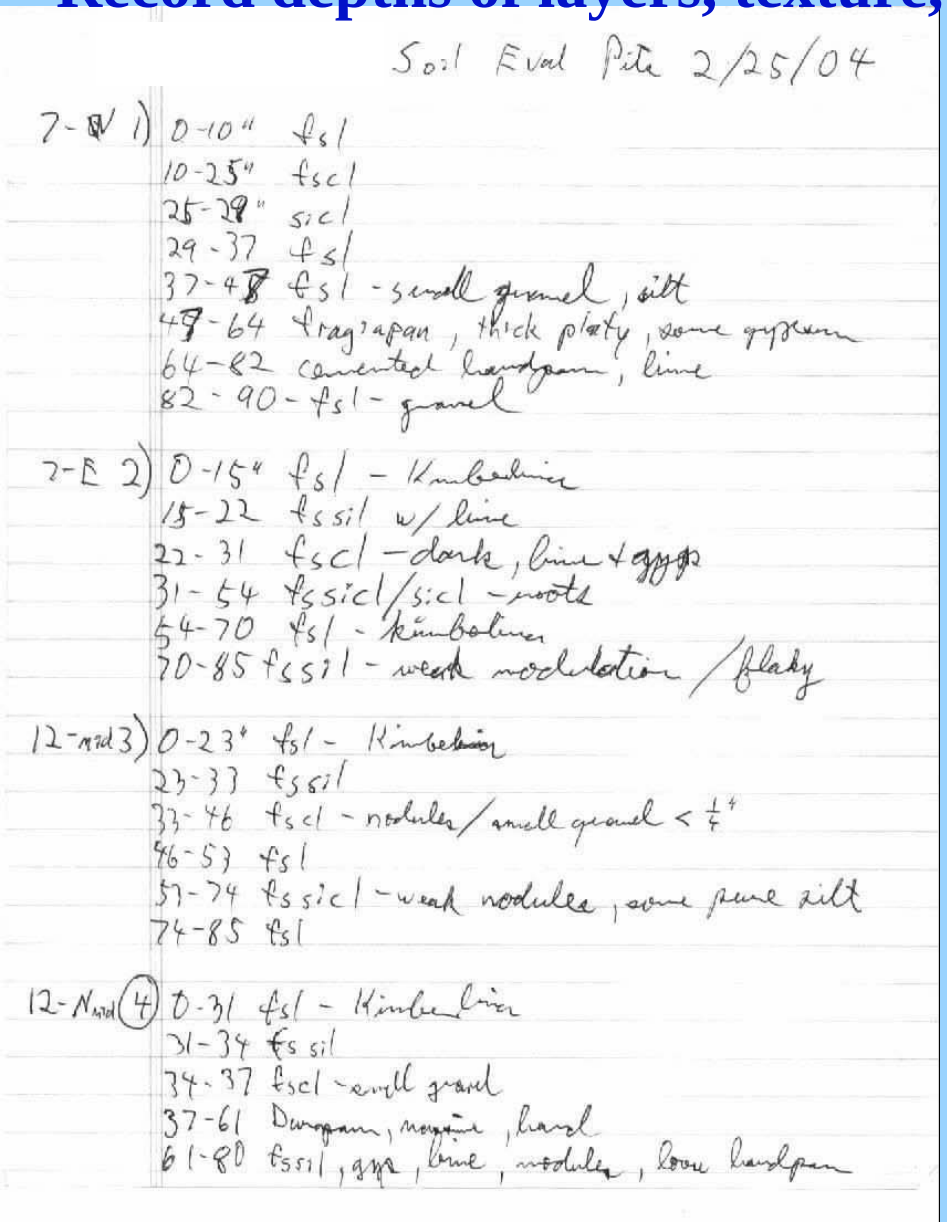

Perched water @ 3.5
foot below berm.
EC = 61 dS/m
2x salinity of seawater

Areas of “black alkali” have been associated with shoot die-back in the spring and apparent frost damage …

… but not uniformly. We are unsure whether tree genetic or soil variability is the major factor.

How to do it

Record depths of layers, texture, lime, hardpans, rooting, drainage



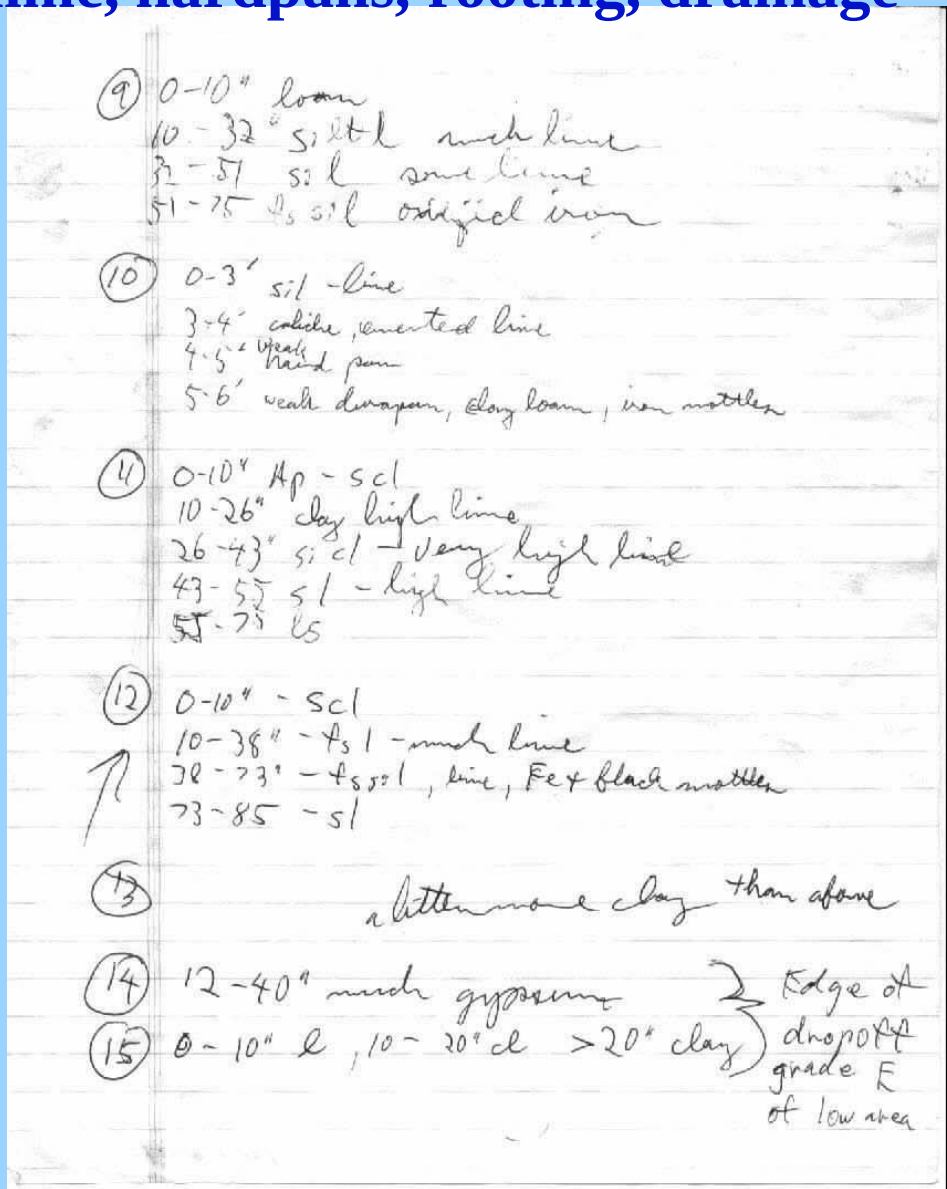
Soil Eval Pits 2/25/04

7-W 1) 0-10" fsl
10-25" fscl
25-29" sicl
29-37 fsl
37-48 fsl - small gravel, silt
48-64 frag'apan, thick platy, some gypsum
64-82 cemented hardpan, lime
82-90 - fsl - gravel

7-E 2) 0-15" fsl - Kimberlina
15-22 fssil w/ lime
22-31 fscl - dark, lime + gyp
31-54 fssicl/sicl - roots
54-70 fsl - Kimberlina
70-85 fssil - weak nodulation / flaky

12-Mod 3) 0-23" fsl - Kimberlina
23-33 fssil
33-46 fscl - nodules / small gravel < ¼"
46-53 fsl
53-74 fssicl - weak nodules, some pure silt
74-85 fsl

12-N Mod (4) 0-31 fsl - Kimberlina
31-34 fs sil
34-37 fscl - small gravel
37-61 Duripan, massive, hard
61-80 fssil, gyp, lime, nodules, loose hardpan



(9) 0-10" loam
10-32" sil + l much lime
32-51 sil some lime
51-75 fs sil oxidized iron

(10) 0-3' sil - lime
3-4' calcite, cemented lime
4-5' weak hard pan
5-6' weak duripan, clay loam, iron mottles

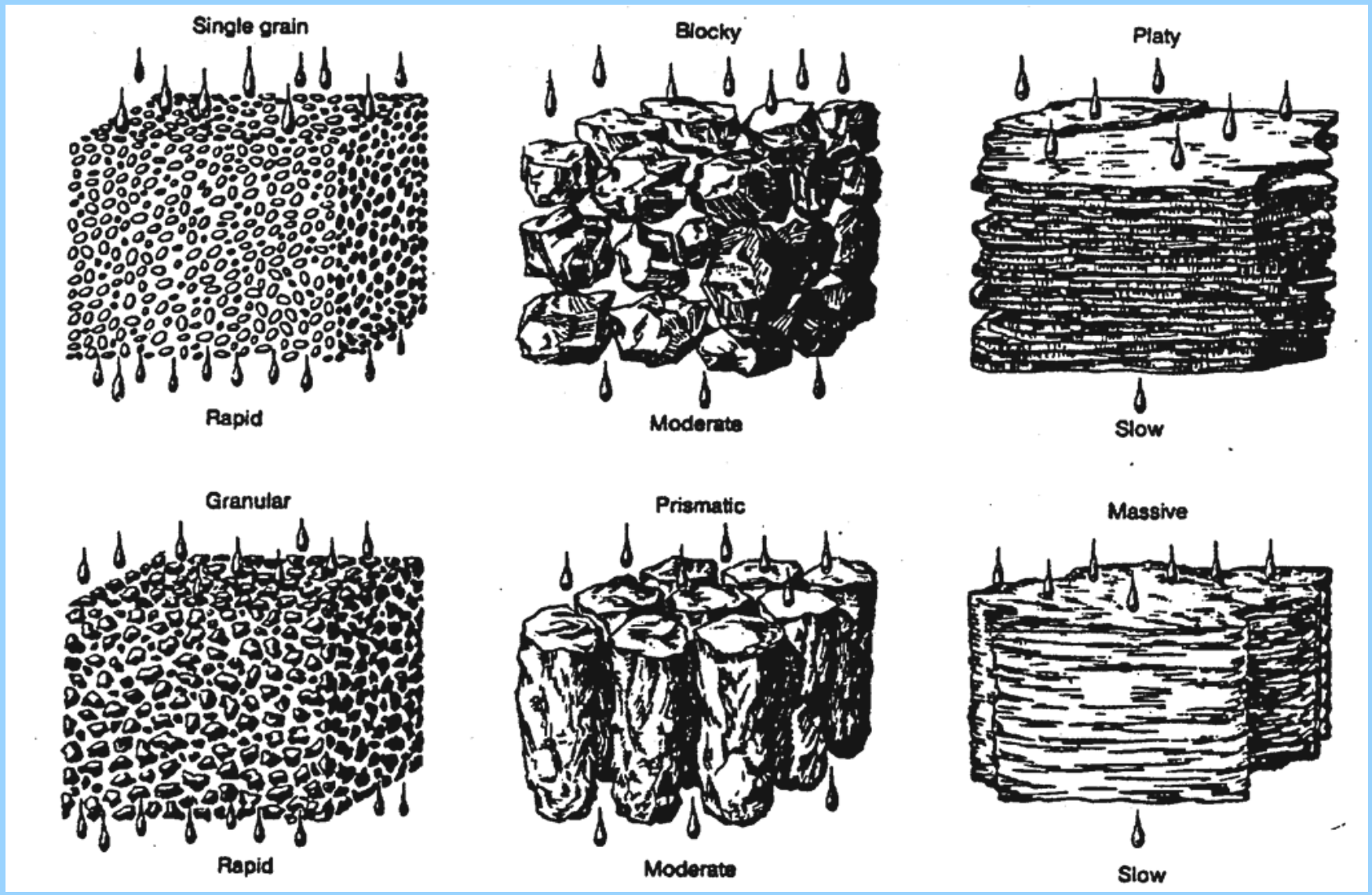
(11) 0-10" Ap - scl
10-26" clay high lime
26-43" sicl - very high lime
43-53 sl - high lime
53-75 ls

(12) 0-10" - scl
10-38" - fs l - much lime
38-73" - fssicl, lime, Fe + black mottles
73-85 - sl

(13) a little more clay than above

(14) 12-40" much gypsum
(15) 0-10" l, 10-20" cl >20" clay } Edge of drop off grade E of low area

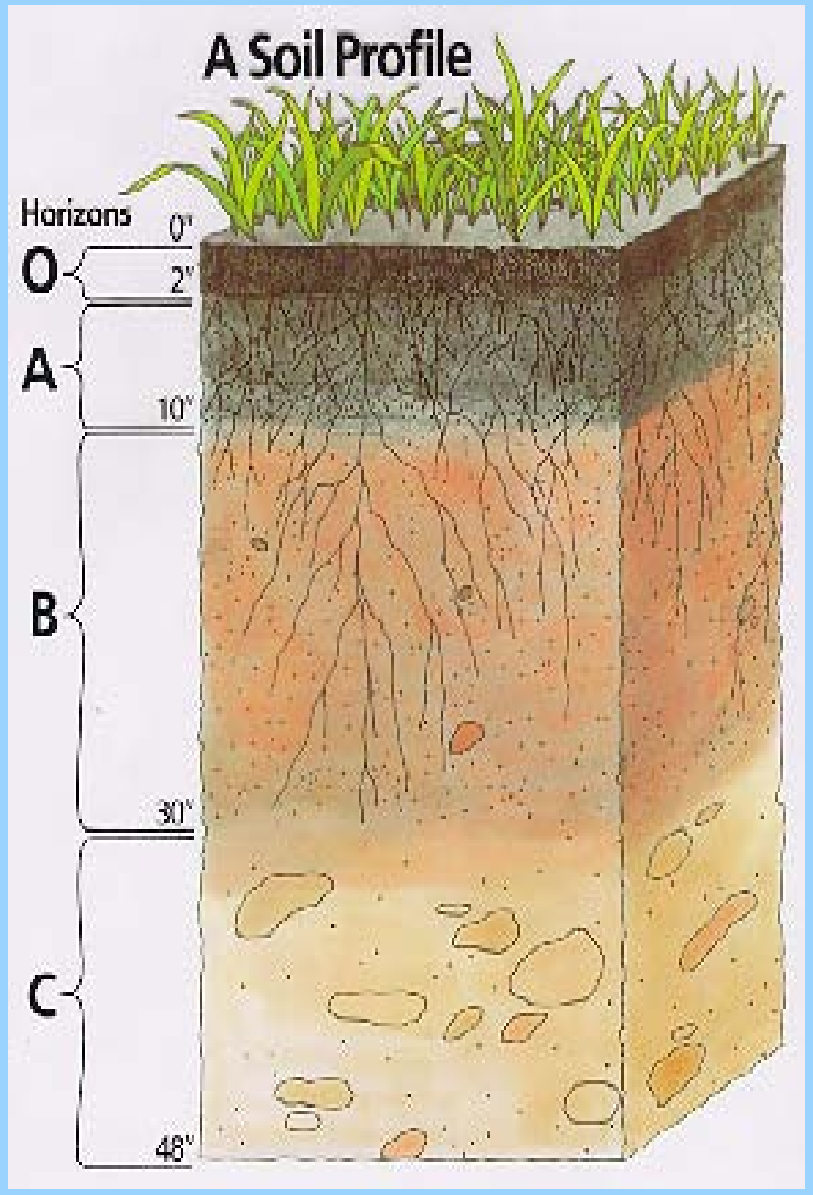
• SOIL PROFILE -- STRUCTURE



What to evaluate?

- **SOIL PROFILE**

- TEXTURE
- STRUCTURE
- PERMEABILITY
- **STRATIFICATION**
- DRAINAGE
- SALINITY/Fertility

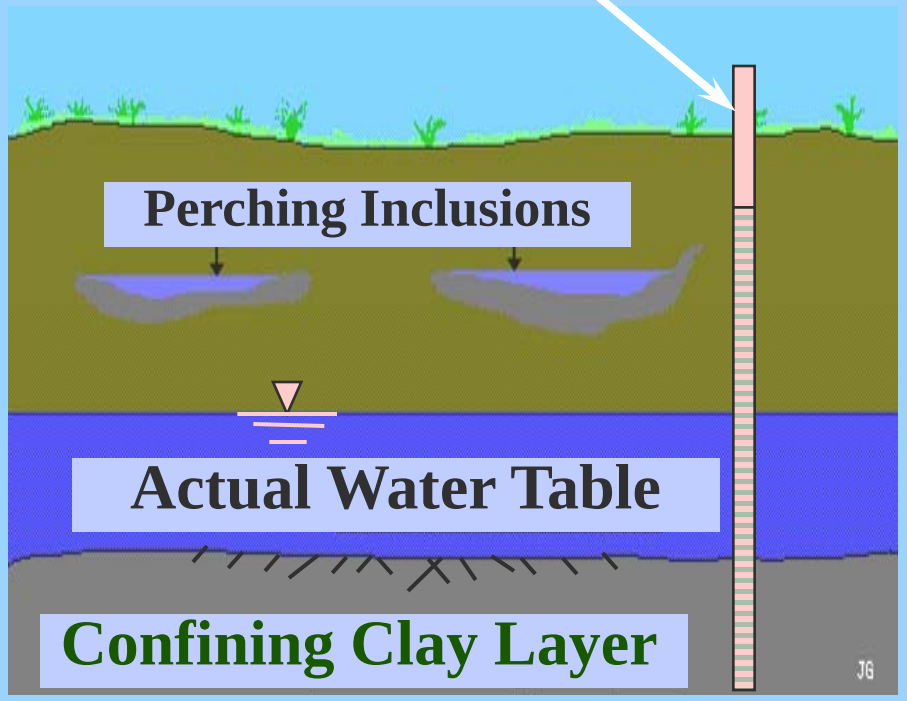


What to evaluate?

- **SOIL PROFILE**

- **TEXTURE**
- **STRUCTURE**
- **PERMEABILITY**
- **STRATIFICATION**
- **DRAINAGE**
- **SALINITY/Fertility**

Monitoring well to determine shallow water table depth



How to do it

Submit soil and water samples to a CERTIFIED ag lab.

FRUIT GROWERS LABORATORY, INC.

ANALYTICAL CHEMISTS

October 7, 2003

Lab ID : VI 342083-06
Customer ID: 4-18085

Sampled On : September 19, 2003
Sampled By : Neil Jessup
Received On: September 24, 2003
Depth : 0-36"

Description : Site 6 Pistachio
Project : Goose Lake Farms

PISTACHIO SOIL ANALYSIS

Test Description	Result		Optimum Range
Primary Nutrients			
Nitrate-Nitrogen	4.9	PPM	See Note 1
Phosphorus	6	PPM	12 - 60
Potassium (Exch)	120	PPM	81 - 500
Potassium (Sol)	ND	meq/L	0.25 - 1.0
Secondary Nutrients			
Calcium (Exch)	4800	PPM	---
Calcium (Sol)	19.2	meq/L	2.0 - 50
Magnesium (Exch)	100	PPM	---
Magnesium (Sol)	1.2	meq/L	1.5 - 60
Sodium (Exch)	500	PPM	---
Sodium (Sol)	50.6	meq/L	See SAR
Sulfate	9.9	meq/L	0.6 - 20
Micro Nutrients			
Zinc	0.5	PPM	0.7 - 50
Manganese	5.2	PPM	1.4 - 50
Iron	5.0	PPM	8.0 - 100
Copper	0.7	PPM	0.2 - 40
Boron	1.2	PPM	0.3 - 1.5
Chloride	53.3	meq/L	0.1 - 4.0
CEC	27.1	meq/100g	Variable
% Base Saturation			
CEC - Calcium	87.8	%	60 - 80
CEC - Magnesium	3.0	%	10 - 20
CEC - Potassium	1.1	%	2 - 5
CEC - Sodium	8.0	%	0 - 5
CEC - Hydrogen	0.0	%	0 - 3
pH	7.5	---	6.8 - 8.2

Graphical Results Presentation: Very Low | Moderately Low | Optimum | Moderately High | Very High; pH: Strongly Acidic | Moderately Acidic | Near Neutral | Moderately Alkaline | Strongly Alkaline

Good — Problem — Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

BPa:

Table continued next page...

Corporate Offices & Laboratory
PO Box 272 / 853 Corporation Street
Santa Paula, CA 93061-0272
TEL: 805/659-0910
FAX: 805/525-4172

Office & Laboratory
2500 Stagecoach Road
Stockton, CA 95215
TEL: 209/942-0181
FAX: 209/942-0423

Field Office
Visalia, CA
TEL: 559/734-9473
FAX: 559/734-8435
Mobile: 559/737-2399

October 7, 2003

Lab ID : VI 342083-06
Customer ID: 4-18085
Description : Site 6 Pistachio

PISTACHIO SOIL ANALYSIS

Test Description	Result		Optimum Range
Others			
Soil Salinity	6.89	mmhos/cm	0.5 - 2.0
SAR	16.3		0.1 - 6
Limestone	1.5	%	See Note 2
Lime Requirement	0.0	Tons/AF	---
Moisture	2.9	%	1/2 Satn. %
Saturation	25.5	%	20 - 60

Graphical Results Presentation: Satisfactory | Possible Problem | Moderate Problem | Increasing Problem; 0 | 1 | 2 | 3 | 4 | 5 | 6; Very Low | Moderately Low | Optimum | Moderately High | Very High; Loamy Sand | Sandy Loam | Loam | Silt Loam | Clay Loam | Clay | Organic

Good — Problem — Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

BPa:

1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.
2) The presence of limestone may result in some chlorosis (yellowing) of the leaves, depending upon the tolerance of the rootstock used.

FRUIT GROWERS LABORATORY, INC.

DHN:meh

Darrell H. Nelson, President

How to do it

- **Soil and Water Analyses**

GROWERS TESTING SERVICES
1525-A EAST ACEQUIA AVE.
VISALIA CA 93292
(559)732-8378 fax(559)627-5460

SOIL ANALYSIS for: [ ] Date Received Date Reported

Pits 8, 9, 11, 12 +13

GTS #	Description	% SP	pH	Saturation Extract mmhos/cm ECe	meq/l Ca	Mg	Na	K	Cl	HCO3	ppm B	Exchangeable Cations meq/100 grams K	Ca	Mg	Na	Soluble Salts % ESP*	% ESP++	Nutr ppm NO3-N	NO3-N dry
4874	(8-13) 0-1'	40.	7.9	5.5	34.23	4.61	21.75	0.17	9.4	3.0	0.57	0.43	24.80	1.60	2.13	7.4	5.70	17.	7
4875	(8-13) 1-2'	45.	8.0	6.7	29.89	4.28	39.58	0.10	14.2	1.3	1.28	0.25	67.07	2.10	3.61	4.9	11.40	48.	22
4876	(8-13) 2-3'	45.	8.0	7.3	25.05	3.95	51.76	0.10	10.8	1.1	2.05	0.19	68.21	1.93	4.65	6.2	15.80	31.	14
4878	(8-13) 3-4'	48.	8.2	13.9	24.40	3.86	126.14	0.08	15.4	1.2	3.27	0.17	43.46	1.77	10.40	18.6	32.50	32.	15
4879	(8-13) 4-5'	48.	8.0	15.2	23.75	3.78	152.24	0.10	25.2	1.6	3.65	0.23	27.74	1.52	11.70	28.4	37.20	27.	13

Received Tue Mar 19 10:17AM

* ESP = (Calculated from Exchangeable Cations)
++ ESP = (Calculated from Soluble Salts and SAR)
*** CEC = (Cation Exchage Capacity)

GTS #	Description	Trace Metals ppm Zn	Mn	Fe	Cu	Free Lime	% CaCO3	ppm SO4-S	% SAR	*** % CEC
4875	(8-13) 0-1'	1.6	8.8	9.6	1.1	HIGH	7.5	121.	29.0	88.8
4876	(8-13) 1-2'	1.1	1.0	8.2	0.8	HIGH	7.4	564.	73.0	88.8
4877	(8-13) 2-3'	1.3	0.8	6.0	0.4	HIGH	6.0	610.	75.0	88.8
4878	(8-13) 3-4'	1.4	0.7	8.2	0.4	HIGH	3.0	640.	55.8	88.8
4879	(8-13) 4-5'	1.3	0.7	10.0	0.4	HIGH	4.5	236.	41.2	88.8

Different labs have different formats. Stick to one lab with consistent, quality results and a format you understand.

How to do it

How to fix it

- **SOIL SALINITY**

FIX: Monitor soil EC, calculate reclamation leaching

Gooselake soils data – composite pits 8, 9, 11, 12, 13

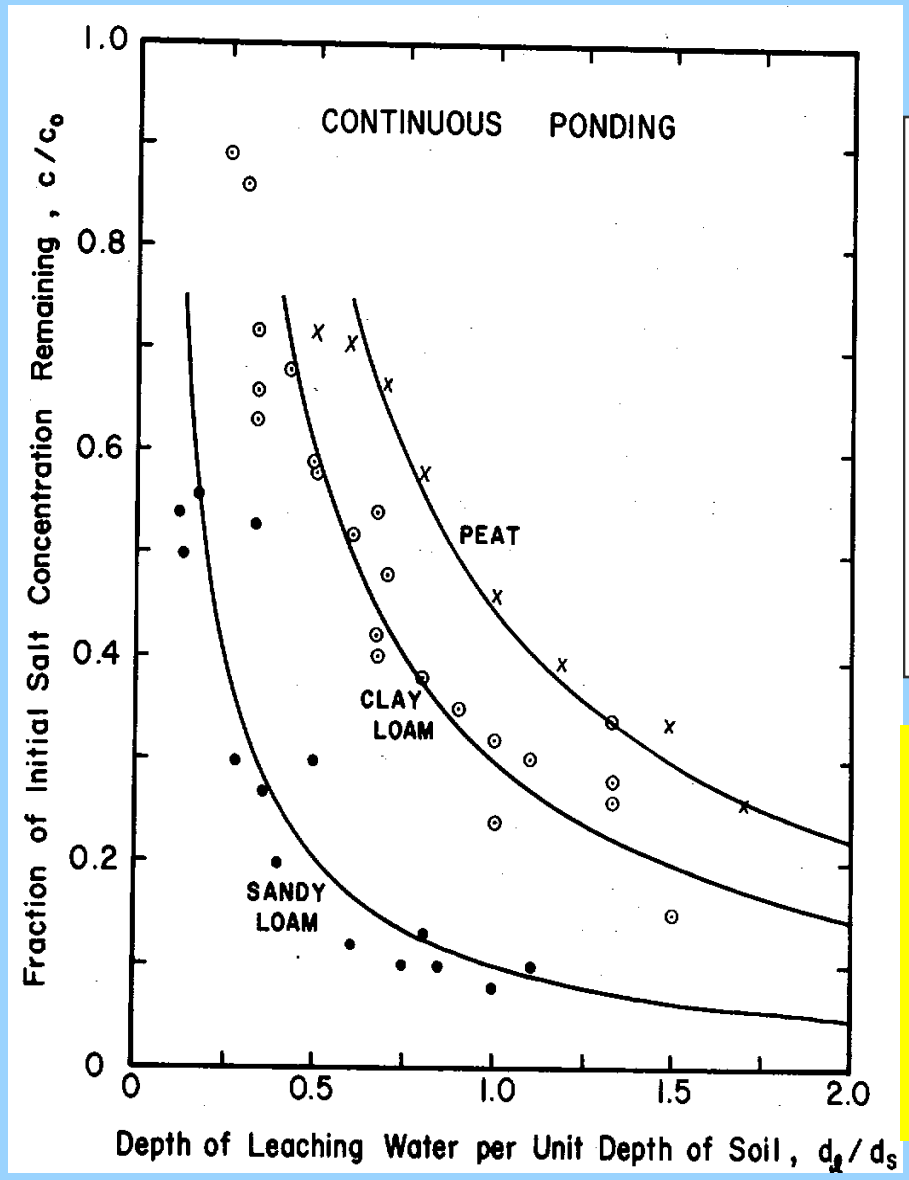
Depth	SP	pH	EC	Ca	Mg	Na	SAR	ESP
0-1'	40	7.9	5.5	34.2	4.6	21.7	4.9	5.7
1-2'	45	8.0	6.7	29.9	4.3	39.6	9.6	11.4
2-3'	45	8.0	7.3	25.1	4	51.8	13.6	15.8

Table 4. Guidelines to evaluate orchard soils and water supplies for excess salinity for mature pistachio trees

	Degree of restriction for pistachios		
EC (dS/m) of:	None	Increasing	Severe
Avg. root zone[1]	< 6	6 - 8	> 8-12
Irrigation water[1]	< 4	4 - 8	> 8-12

[1] Guidelines based on field data where the annual leaching fractions were about 15% for the "No restriction level" and 30% for the "Severe Level".

How to do it How to fix it



•SOIL SALINITY/LEACHING

Desired Rootzone Salinity (dS/m)	*Inches of water/foot of rootzone Required to leach initial salinity of: 6 dS/m	8 dS/m	10 dS/m	12 dS/m
3	1.2	2.0	2.8	3.6
5	0.2	0.7	1.2	1.7
7	0	0.2	0.5	0.9

*Applicable for all irrigation waters less than 1.0 dS/m. Adapted from research reported by Hoffman, G.J. 1986. Guidelines for reclamation of salt-affected soils. Applied Agricultural Research, Vol. 1(2):65-72.

<u>FIX</u>: Apply appropriate depth of leaching to achieve rootzone salinity target. About 5” to go from EC = 6 to EC = 3 to a depth of 3 feet.

How to do it How to fix it

•SOIL SALINITY/LEACHING

LEACHING ESTIMATE FOR UNDEVELOPED PISTACHIO GROUND (SITES 8,9,11,12,13)

(Data from Grower's Testing Analysis for Goose Lake Project)

CALCULATING SAR, ESP AND DESIRED LEACHING DEPTH

EXAMPLE	Data Required from Soil Extract Analysis (%)		(dS/m)		(meq/l)					Desired	Dsrd/Orig	Sprinkling/Drip Reqd Depth to Leach
Depth	SP	pH	EC	Ca	Mg	Na	SAR	ESP	EC/ESP	Salinity	EC	(ft water/ft soil)
0-1'	40	7.9	5.5	34.2	4.6	21.7	4.9	5.7	1.0	3	0.55	**0.13**
1-2'	45	8.0	6.7	29.9	4.3	39.6	9.6	11.4	1.7	3	0.45	**0.19**
2-3'	45	8.0	7.3	25.1	4	51.8	13.6	15.8	2.2	3	0.41	**0.22**
										TOTAL DEPTH OF LEACHING (feet of water) FOR 3 FEET:		**0.53**

Always want EC/ESP < 5 to avoid serious infiltration problems.

To calculate SAR: SAR = Na / SqRt(Ca+ Mg/2)

To calculate ESP from SAR: ESP = 100*(0.01475*SAR - 0.0126)/(1+ (0.01475*SAR - 0.0126))

Required Leaching (ft water/ft depth soil) = K / (Desired EC/Original EC) - K

(K factor of 0.3 for continuous ponding.)

(K factor of 0.15 for sprinkling or drip.)

Hoffman, G.J. 1996. "Leaching fraction and root zone salinity control." Agricultural Salinity Assessment and Management. ASCE. New York, N.Y. Manual No. 7:237-247

FIX: a 0.5 ft depth of water over the berm area would be sufficient to decrease EC to 3 dS/m to a 3 ft depth and establish trees.

How to do it

- **SOIL SALINITY**

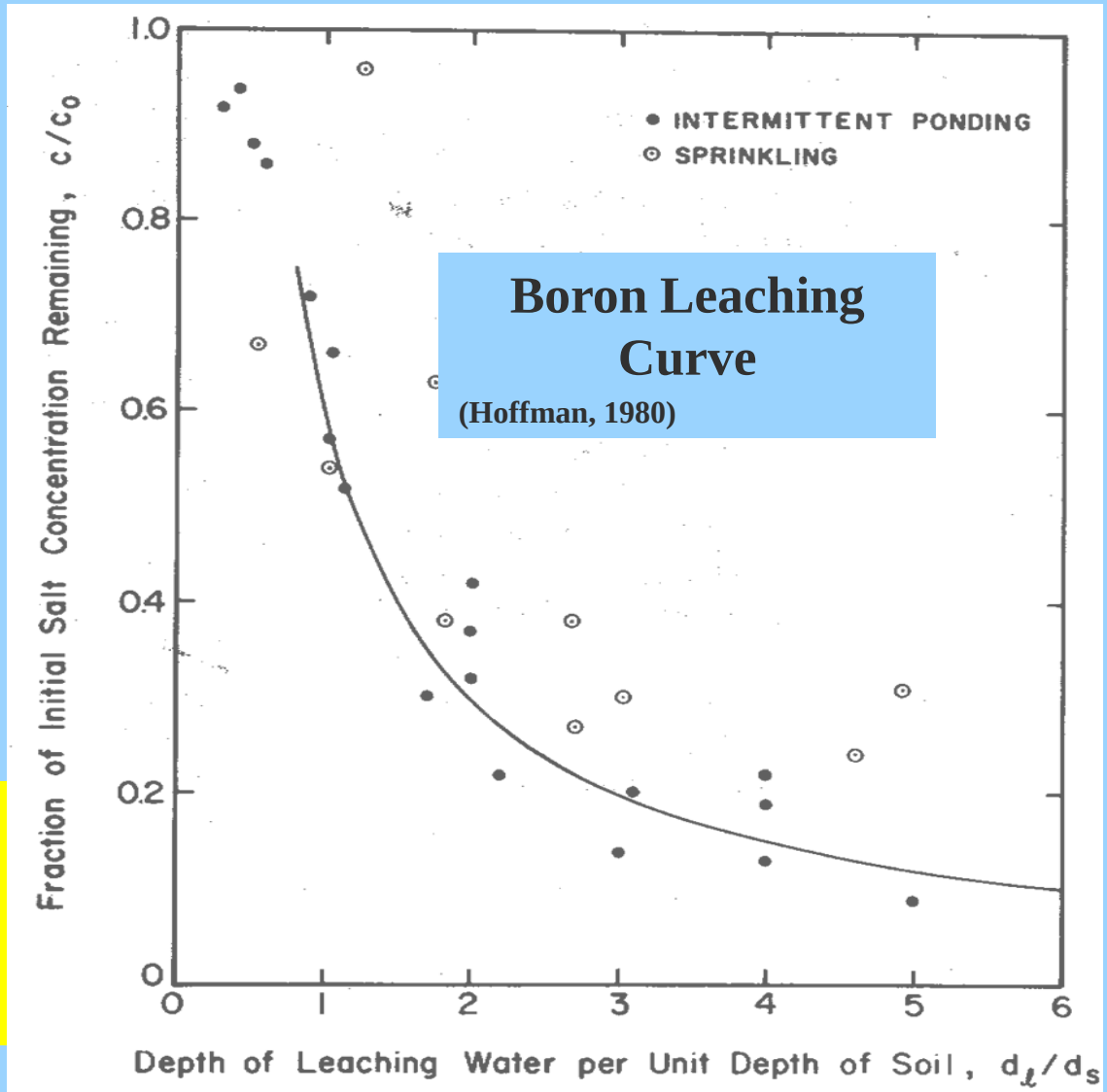
BORON

Analysis:

SP	48
pH	8.2
EC_e	6.0 dS/m
Ca	8.6 meq/l
Mg	2.1 meq/l
Na	62 meq/l
B	**1.8 mg/l**
SAR	27
ESP	28
GR	16.6 t/ac-ft

FIX: Leaching boron requires 3 times as much water as leaching general salts

FIX: No problem up to 10 ppm. Below 1 ppm, add 20 lb/ac Solubor for 1 ppm increase in top foot of soil.



Determining Leaching Fraction to maintain desired rootzone salinity

Table 3 CONCENTRATION FACTORS (X) FOR PREDICTING SOIL SALINITY (ECe)1 FROM IRRIGATION WATER SALINITY (ECw) AND THE LEACHING FRACTION (LF)

Leaching Fraction (LF)	Applied Water Needed (Percent of ET)	Concen-tration Factor (X)
0.05	105%	3.2
0.1	111%	2.1
0.15	118%	1.6
0.2	125%	1.3
0.25	133%	1.2
0.3	143%	1
0.4	167%	0.9
0.5	200%	0.8
0.6	250%	0.7
0.7	333%	0.6
0.8	500%	0.6

Applied water needed = 1/(1-LF)

Ayers, R.S., D.W. Westcot. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1, Reprinted 1989, 1994 .
http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm

Leaching fraction required over long-term irrigation with a given salinity of water to obtain a desired rootzone salinity. (Ignoring precipitation/dissolution reactions in the soil.)

Irrigation Water EC (dS/m)	Desired Average Rootzone ECe 1	2	3	4	5	6	7
0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.4	0.07	0.02	0.01	0.01	0.01	0.00	0.00
0.8	0.23	0.07	0.04	0.02	0.02	0.01	0.01
1.2	0.44	0.14	0.07	0.05	0.03	0.02	0.02
1.6		0.23	0.12	0.07	0.05	0.04	0.03
2.0		0.33	0.17	0.10	0.07	0.05	0.04
2.4		0.44	0.23	0.14	0.10	0.07	0.06
2.8			0.29	0.18	0.13	0.09	0.07
3.2			0.36	0.23	0.16	0.12	0.09
3.6			0.44	0.27	0.19	0.14	0.11
4.0				0.33	0.23	0.17	0.13
4.4				0.38	0.26	0.20	0.15
4.8				0.44	0.30	0.23	0.18
5.2					0.35	0.26	0.20
5.6					0.39	0.29	0.23
6.0					0.44	0.33	0.25
6.4						0.36	0.28

SOLVING FOR DESIRED LEACHING FRACTION DIRECTLY:

Regressing the rootzone salinity concentration factors in FAO29 and rearranging to solve for Leaching Fraction (LF):

LF = 0.326 (Desired ECe/ECirr)^ -1.64

How to do it How to fix it

- **WATER QUALITY**

Analysis:

pH	8.4
EC_w	1.0 dS/m
Ca	0.5 meq/l
Mg	0.1 meq/l
Na	9.6 meq/l
HCO_3	4.2 meq/l
CO_3	1.0meq/l
Cl	4.6meq/l
SO_4	0.1meq/l
B	0.7 mg/l
NO_3	5.2 mg/l
SAR	17.5
SAR_{adj}	16.6

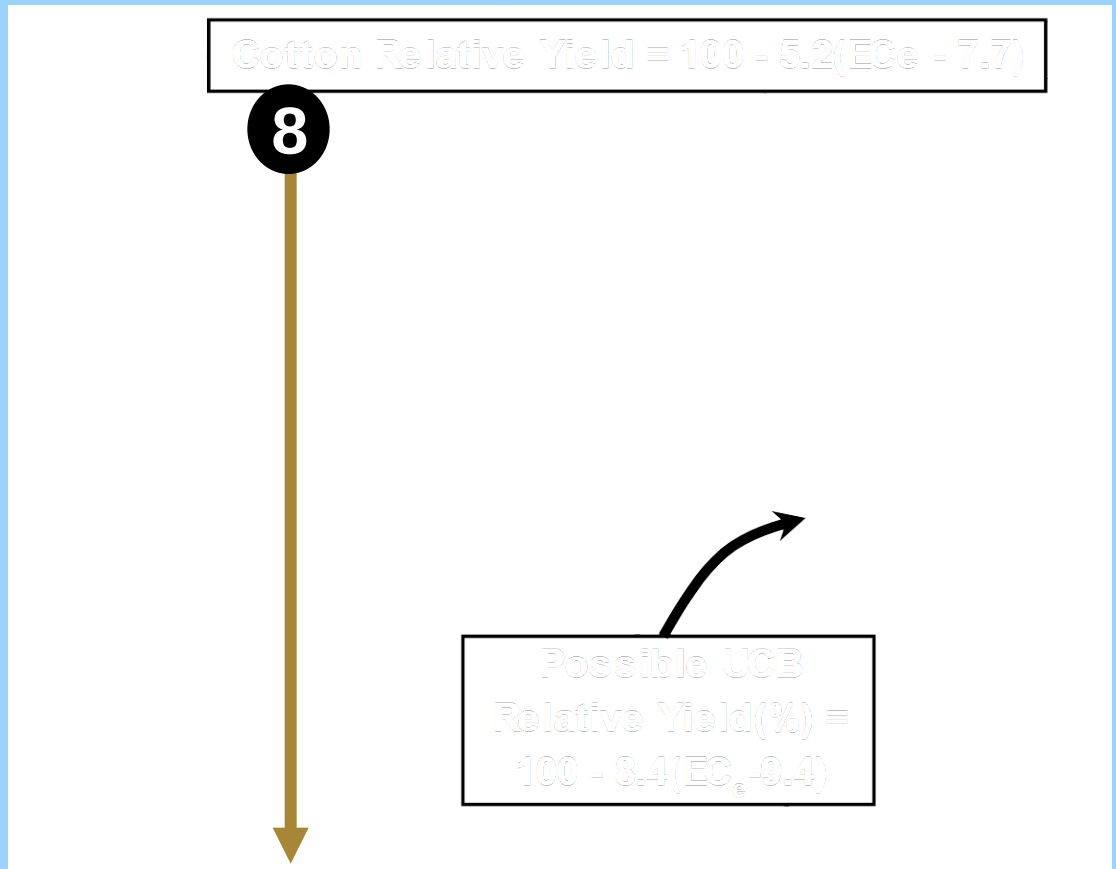


Fig. 2. Relative yield (RY) of various crops as a function of soil EC_e (Sanden, et al., 2004).

FIX: None needed for EC. Maintain normal irrigation.

How to do it

How to fix it

- **WATER QUALITY**

Analysis:

	Aqueduct	Well	
pH	7.4	7.4	
EC_w	0.5	5.4	dS/m
Ca	1.2	23.4	meq/l
Mg	1.0	14.0	meq/l
Na	2.5	23.0	meq/l
HCO_3	1.6	1.5	meq/l
CO_3	<0.1	<0.1	meq/l
Cl	2.0	33.5	meq/l
SO_4	0.9	24.0	meq/l
B	0.3	11.0	mg/l
NO_3	0.6	8.0	mg/l
SAR	2.4	5.4	

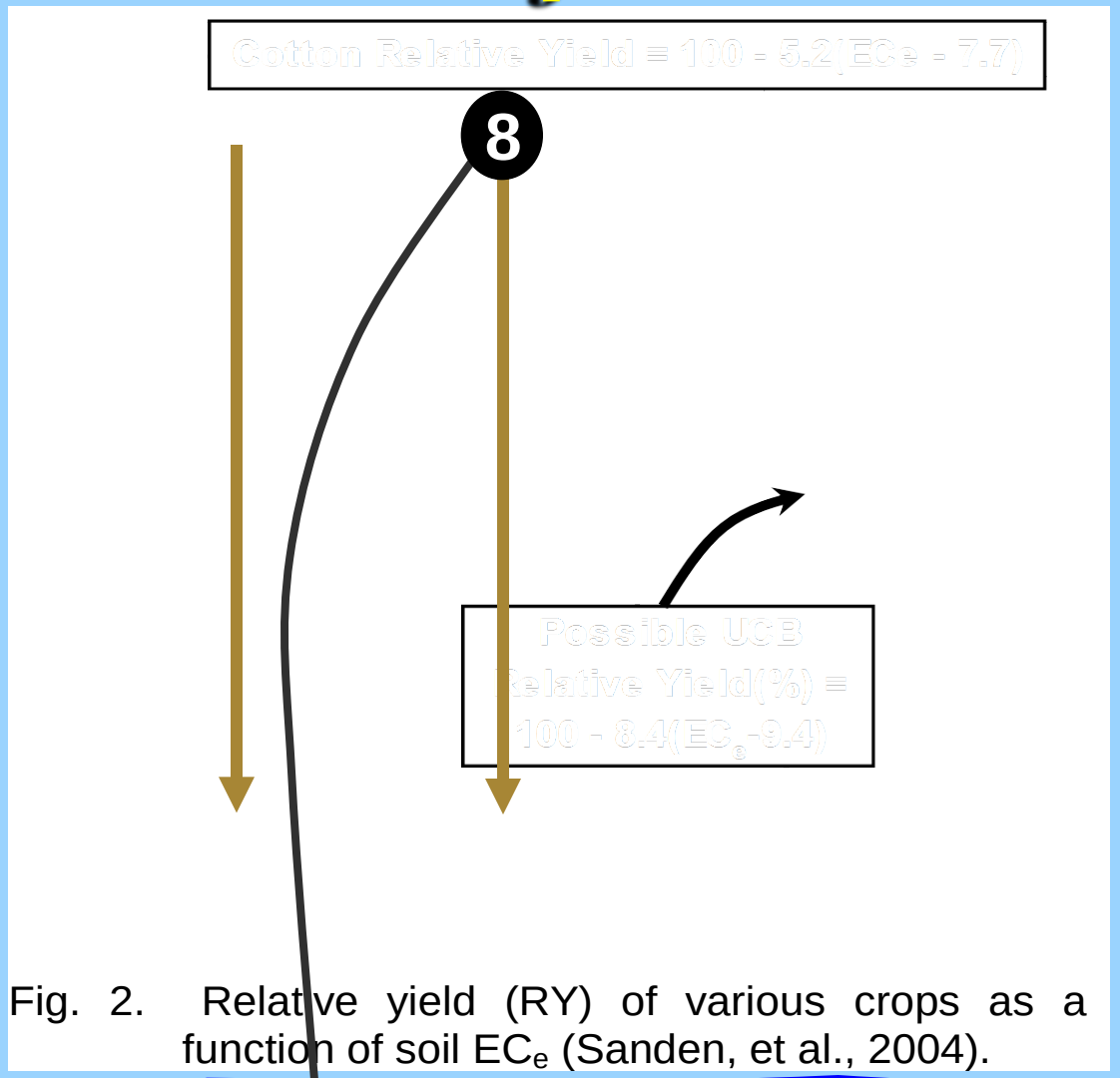


Fig. 2. Relative yield (RY) of various crops as a function of soil EC_e (Sanden, et al., 2004).

FIX: Increase WELL **Leaching Rqt = $ECw/(5ECe_{desired} - ECw)$**

For desired rootzone ECe of 8, LR = 16%, ECe of 6, LR = 22%

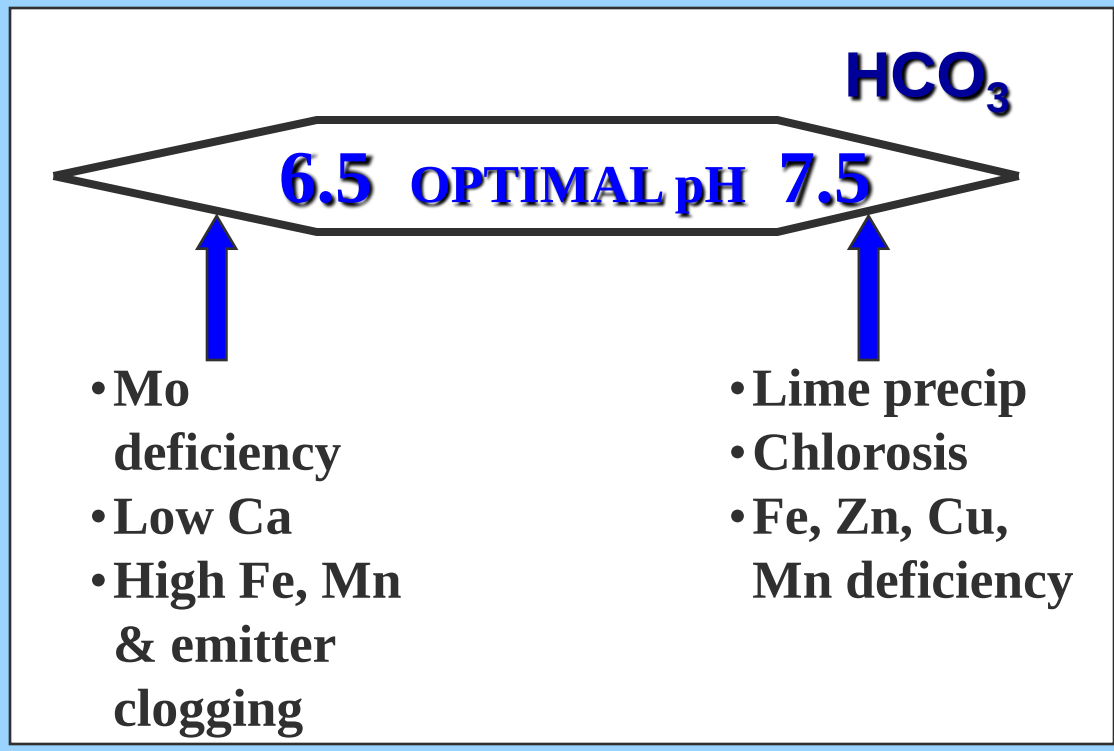
How to do it

How to fix it

- **WATER QUALITY**

Analysis:

	Well 1	Aque	Well 2	
pH	**8.4**	**7.4**	**7.4**	
EC_w	1.0	0.5	5.8	dS/m
Ca	0.5	1.2	26.5	meq/l
Mg	0.1	1.0	15.3	meq/l
Na	9.6	2.5	23.9	meq/l
HCO_3	**4.2**	**1.6**	**1.5**	**meq/l**
CO_3	1.0	<0.1	<0.1	meq/l
Cl	4.6	2.0	36.9	meq/l
SO_4	0.1	0.9	24.0	meq/l
B	0.7	0.3	11.0	mg/l
NO_3	5.2	0.6	8.0	mg/l
SAR	17.5	2.4	5.4	
SAR_{adj}	16.6			



FIX: Inject acid. 200 - 500 lb/ac-ft H_2SO_4

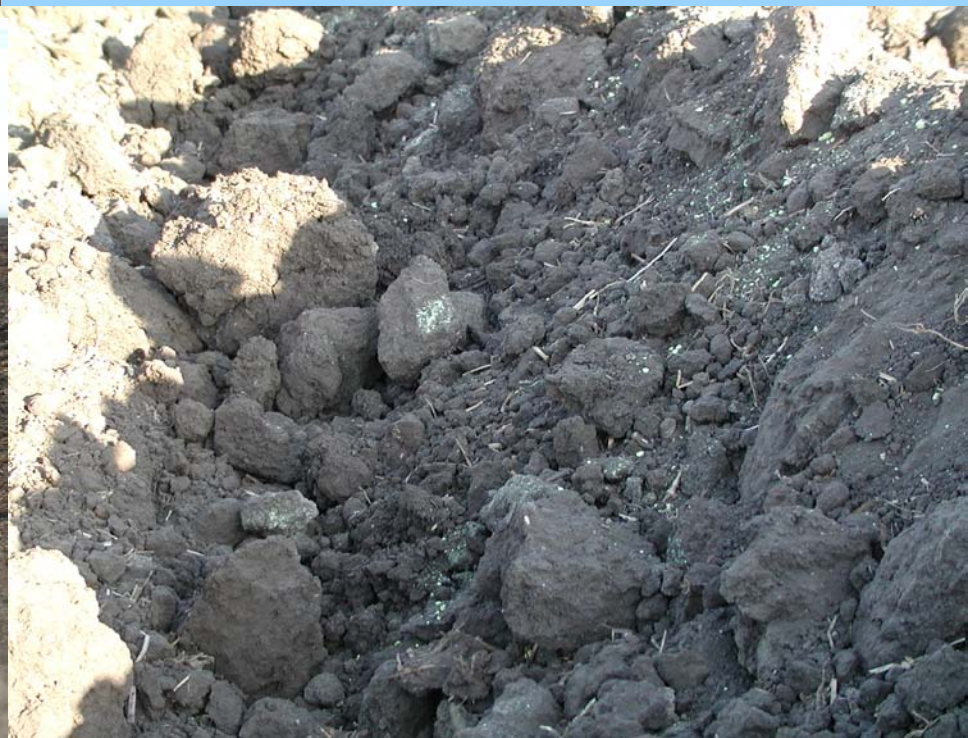
(Use Table 8 for weights of sulfuric and NpHuric reqd to neutralize HCO3 and release Ca from lime.)

- Marginally saline clay loam soils that retain a high degree of moisture after cropping will not fracture as well as drier, more structured profiles.

Fine, ball-milled reclaimed sulfur applied @ 1.5 t/ac

2 foot banded appliation:
= 15 t/ac to reduce pH in tree row

Incorporated with bent 15” furrowing shovel welded to 24” chisel shank and sunk into slip trench



Incorporation to 28” depth

Remember gypsum is also a salt and adds to the osmotic pressure that limits water uptake through the roots

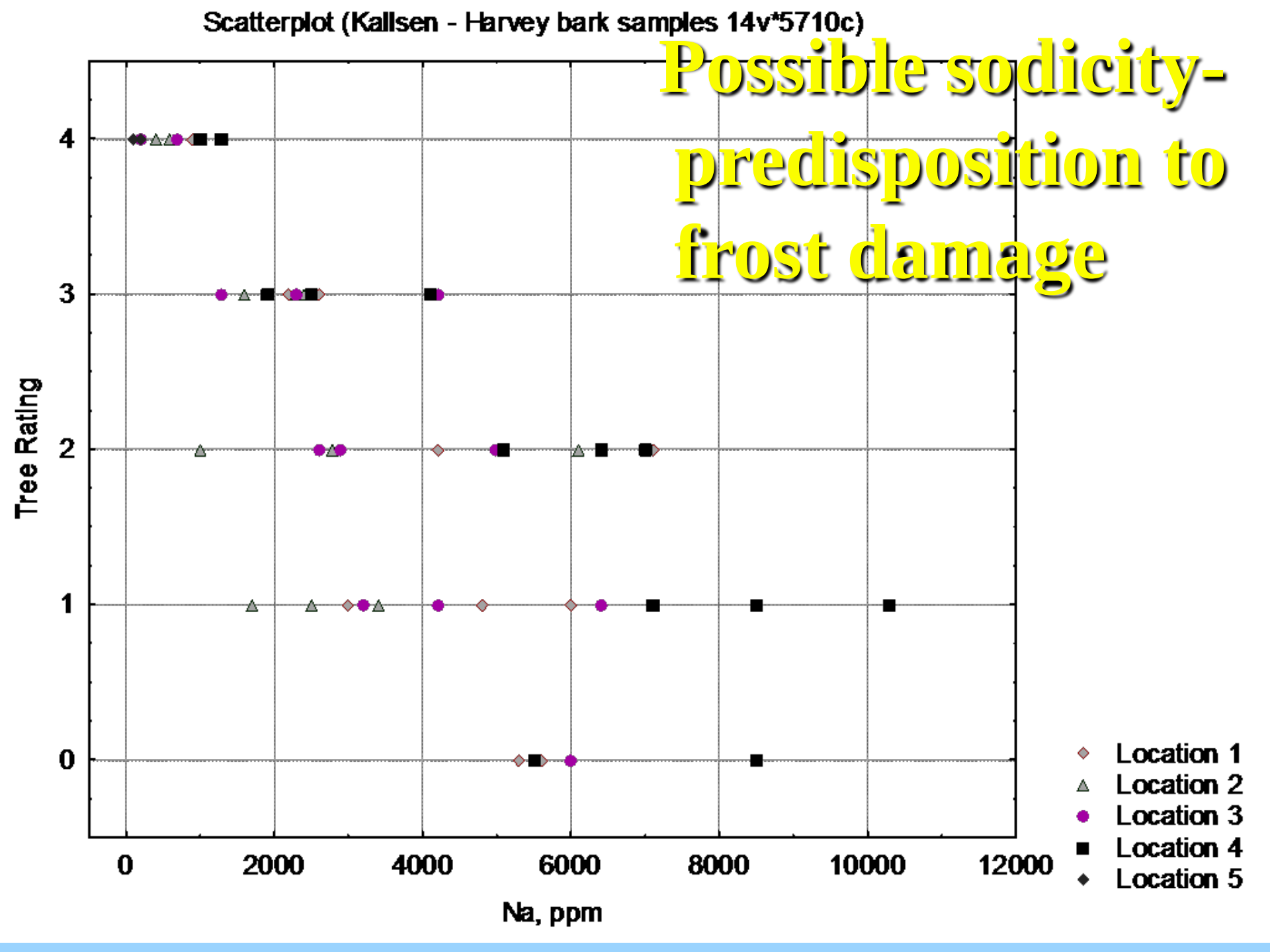
Piling additional gypsum around the tree or injecting into the water may help reduce toxicity symptoms and susceptiblity to frost.

No salt burn evident on rootstock leaves (10/30/07)

Possible sodicity-predisposition to frost damage


Possible sodicity-predisposition to frost damage

Possible sodicity-predisposition to frost damage bark samples for sodium


Scatterplot (Kallsen - Harvey bark samples 14v*5710c)
Possible sodicity-predisposition to frost damage
Tree Rating
Na, ppm
0
1
2
3
4
0
2000
4000
6000
8000
10000
12000
Location 1
Location 2
Location 3
Location 4
Location 5

Salinity management aids on the web

Excel Leaching Calculator

- **Cnvrsn-Infilt-LeachCalc**

2005 Pistachio Production Manual Chapters

- **Managing salinity, soil and water amendments**
- **Site evaluation and soil physical modification**
- **Improving water penetration**

Available for download from the Kern County UCCE Website

http://cekern.ucdavis.edu/Irrigation%5FManagement/

Why evaluate?

- **THE PERFECT GROUND ISN'T ALWAYS WHAT YOU GET**

- **4' of cheap water**
  - **EC 0.6 to 1.2 dS/m**
- **0.1 to 1.5% even slope**
- **Loam to sandy clay loam texture**
- **No perched water, good infiltration**
- **Grows 3.5 bale/ac cotton**

Why evaluate?

- **REALITY**

Most of us make due with what we get!