Assessing and managing salinity in grapes

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More information:

Water Quality and Agriculture FAO 29:

http://www.fao.org/DOCReP/003/T0234e/T0234e00.htm

Use of Saline Water for Crop Production FAO 48:

http://www.fao.org/docrep/t0667e/t0667e00.htm

Agricultural Salinity and Drainage (UCANR Pub. 3375):

http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=3375

Managing Salts by Leaching (UCANR Pub. 8850):

http://anrcatalog.ucanr.edu/pdf/8550.pdf

Drip Irrigation Salinity Management of Row Crops (UCANR Pub. 8447):

http://anrcatalog.ucanr.edu/pdf/8447.pdf

Crop Salt Tolerance (UCANR pub. 8562):

http://anrcatalog.ucanr.edu/pdf/8562.pdf

Demystify salinity management:

- ✓ What is salinity?
- ✓ How is salinity characterized and measured?
- ✓ How do you determine suitability of water for irrigating crops?
- ✓ How much leaching is needed to maintain crop production?

Constituents of salinity

Cations:	Anions:
Ca^{2+}	Cl^- (toxic ion)
Mg^{2+}	SO_4^{2-}
Na^+ (toxic ion)	CO_3^{2-}
K^+	HCO_3^-
	NO_3^-

pH

Alkalinity:

$CO_3^{--} + HCO_3^-$

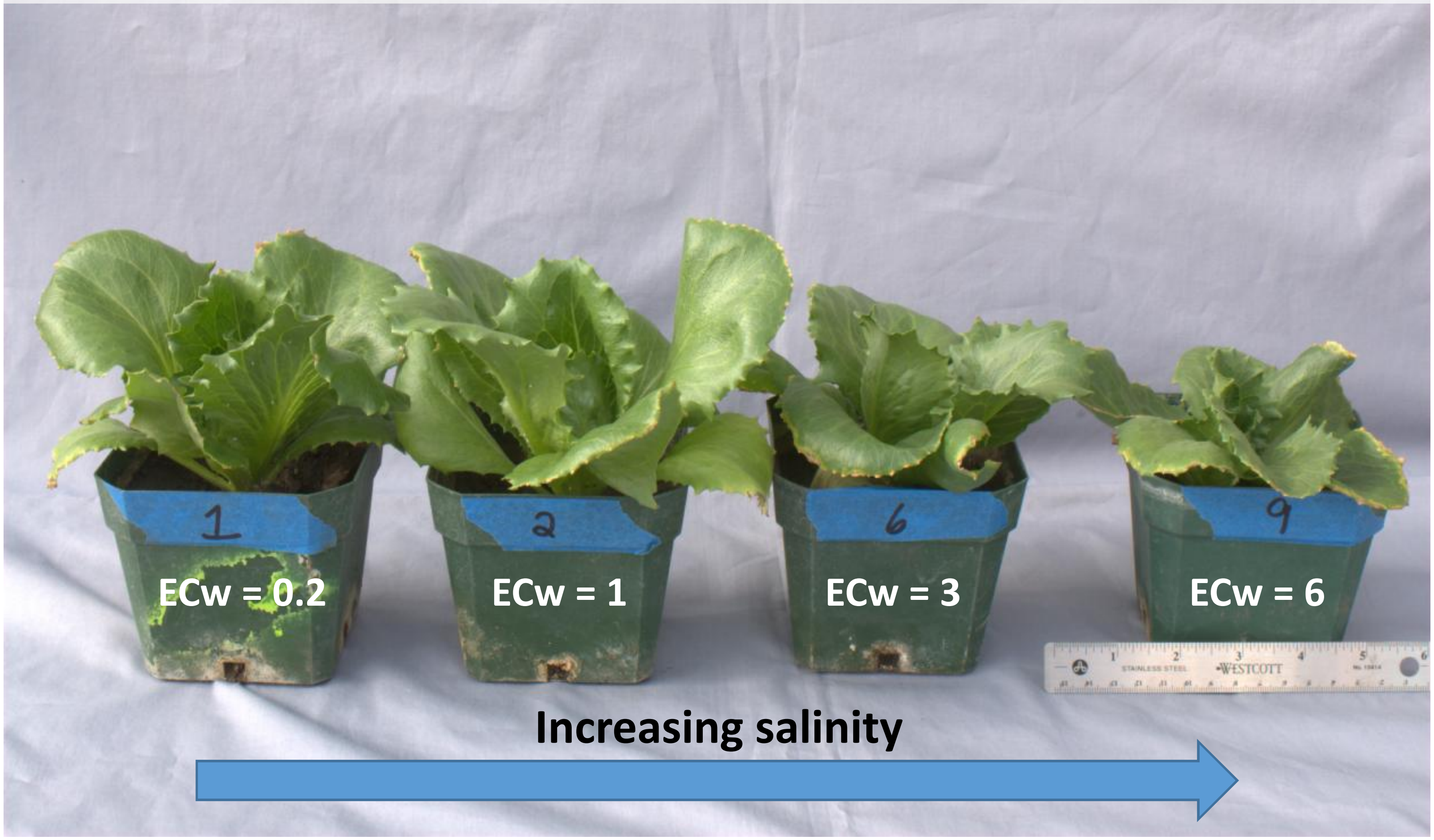
Specific Ion Toxicity:

Na, Cl, Boron

Conversion of units: parts per million (ppm) to milliequivalents of charge (meq)

Cations (+)				Anions (-)			
Name	Symbol	charge	divide by:	Name	Symbol	charge	divide by:
Sodium	Na	+	23	Chloride	Cl	-	35
Calcium	Ca	++	20	Sulfate	SO_4	- -	48
Magnesium	Mg	++	12	Bicarbonate	HCO_3	-	61
Potassium	K	+	39	Carbonate	CO_3	- -	30
Ammonium	NH_4	+	18	Hardness	$CaCO_3$	- -	50
				Nitrate	NO_3	-	62

Osmotic Effect of Salts



Specific Ion Toxicity

Photo credit: www.djsgrowers.com.au

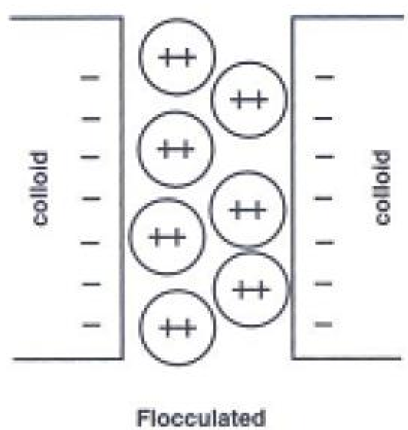
Quantifying Salinity

- Electrical Conductivity (dS/m)
- Total Dissolved Solids (mg/L or ppm)
- Sodium Adsorption Ratio
- Adjusted Sodium Adsorption Ratio
- Exchangeable Sodium Percentage (soil)

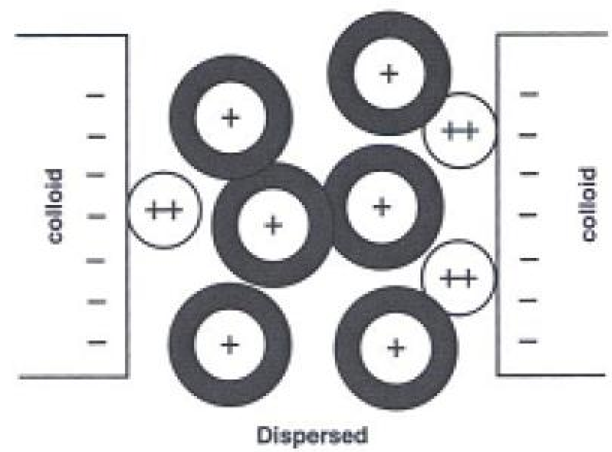
Assessing Soil Sodicity

$$Sodium\ Absorption\ Ratio = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Concentrations in meq/L



Calcium and Magnesium dominated



Sodium dominated

Is your soil saline, sodic or both?

Classification	Salinity (ECe)	Sodicity	pH	Soil aggregate structure
	dS/m	SAR		
Non-saline	< 4	<13	< 8.5	normal
Saline	> 4	<13	< 8.5	normal
Saline-sodic	> 4	>13	< 8.5	some degradation
Sodic	< 4	>13	> 8.5	poor

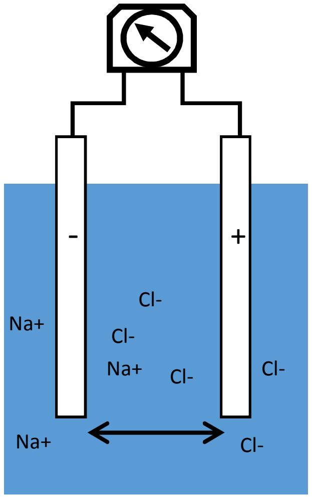
Electrical Conductivity (EC) can be related to salinity

DeciSiemens per meter = dS/m

1 dS/m = 1 mmho/cm = 1 mS/cm
1 dS/m = 1000 µS/cm

EC_w = TDS/640 for EC < 5 dS/m

EC_w = TDS/800 for EC between 5 and 10 dS/m or salts dominated by Calcium

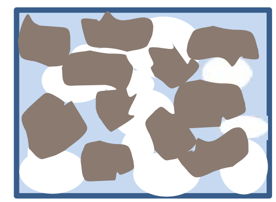


Types of Electrical Conductivity Measurements

EC_w = EC of **w**ater

EC_e = EC of saturated soil paste **e**xtract (extracted with distilled water)

EC_{sw} = EC of **s**oil **w**ater (pore water, drainage water)



EC_a = EC_b = **a**pparent or **b**ulk soil EC

Converting among EC Measurements

$EC_e = EC_{sw} / 2$

$EC_{sw} = 3 \times EC_w$

$EC_e = A \times EC_w$

A = concentration factor dependent on LF (1.6 for a LF = 0.15)

Field measurements of salinity:

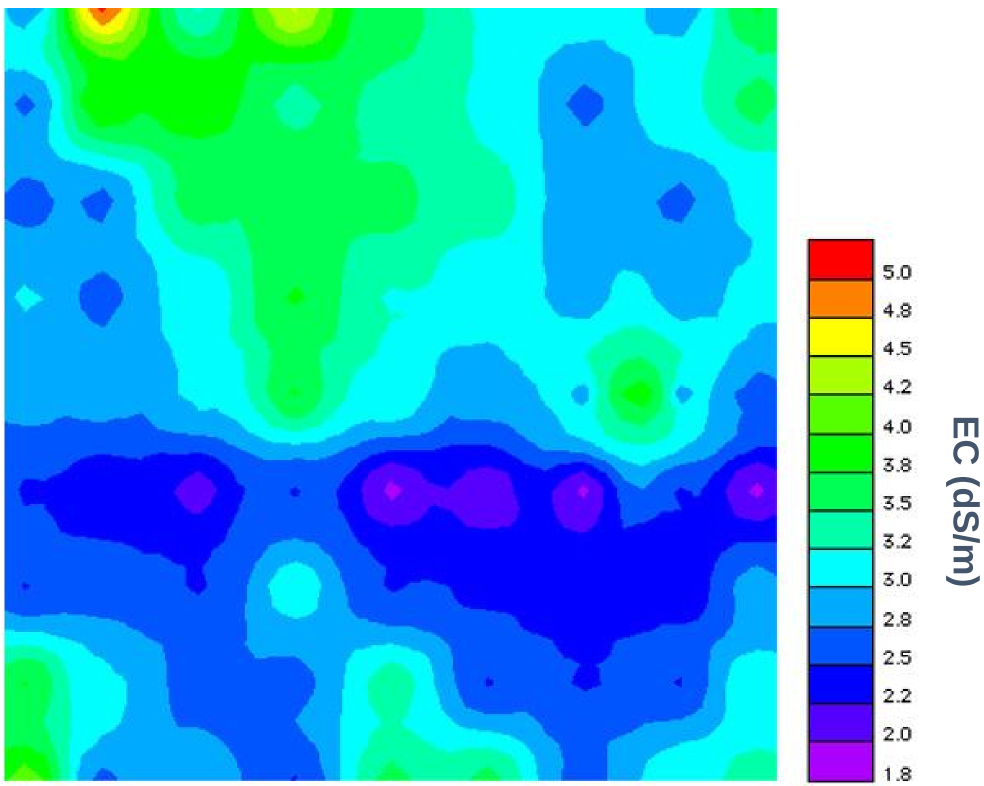
EM 38

Soil Salinity Probe

Suction lysimeter

$$LF = \frac{ECw}{ECsw}$$

Bulk EC Map Using an EM38



Readings affected by:

- **Soil Salinity**
- **Soil Compaction (porosity)**
- **Soil Texture (clay content)**
- **Soil Moisture Content**
- **Soil Temperature**
- **Depth of penetration**

Direct measurements of soil salinity: Decagon 5TE probe

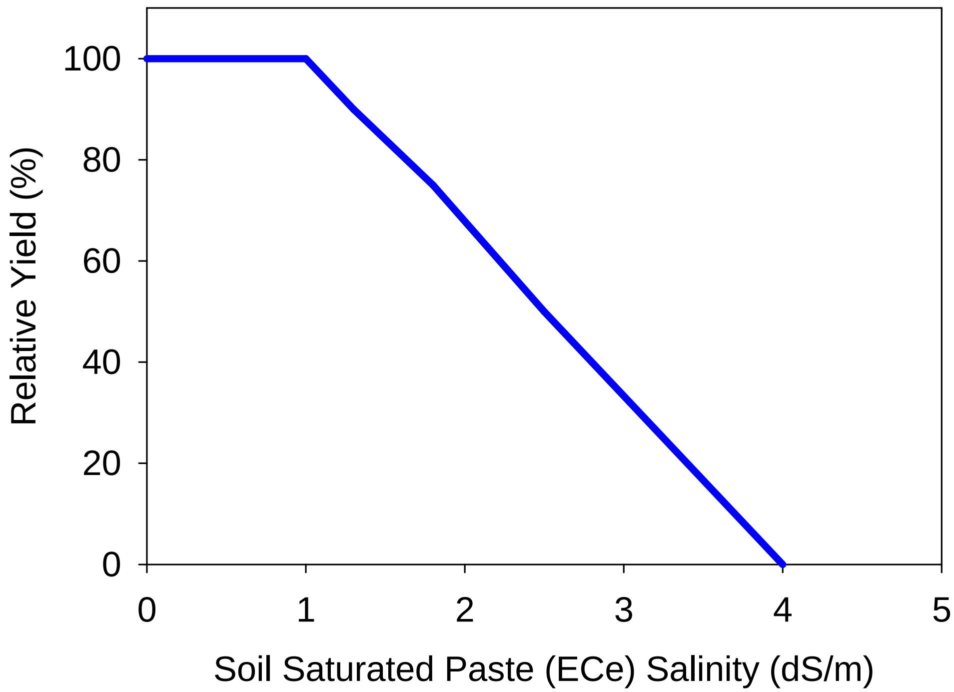
- Measures: ECa, Soil temp, volumetric moisture
- Calibration for ECsw
- Good for assessing relative differences within a field
- Differences in soil moisture and bulk density will still interfere with readings

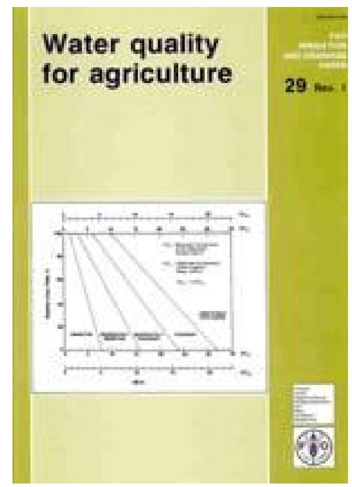
Assessing Suitability of Water for Irrigation

- ✓ Salt tolerance of crop
- ✓ Specific ion sensitivity of crop
- ✓ Irrigation method (sprinkler, drip, flood)

Crop sensitivity to soil salinity is related to ECe

Relative Yield (%) = 100 - slope×(EC_e - EC_e threshold)

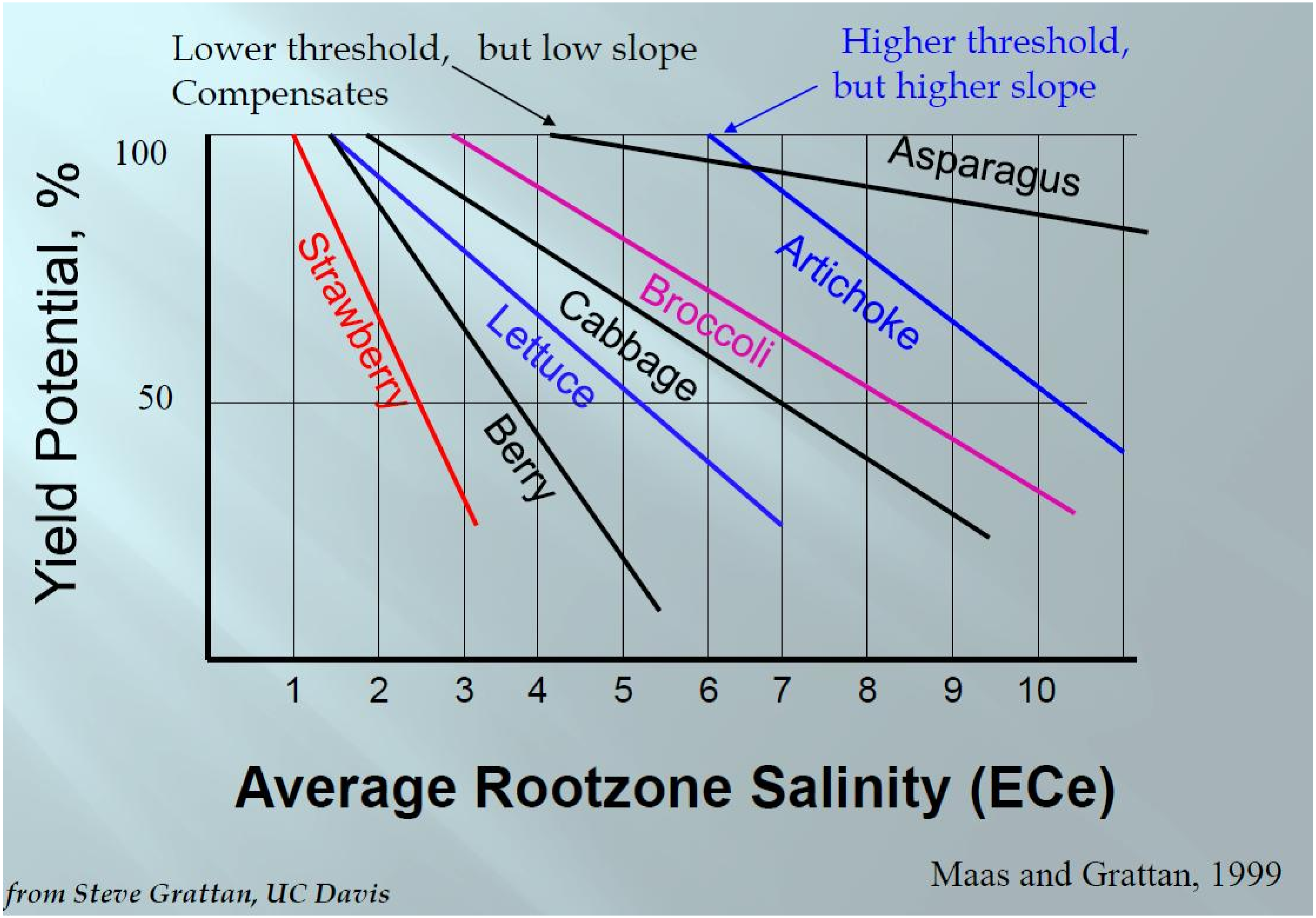




Ayers and Westcot, 1985

Maas and Hoffman, 1977

Crop sensitivity to soil salinity



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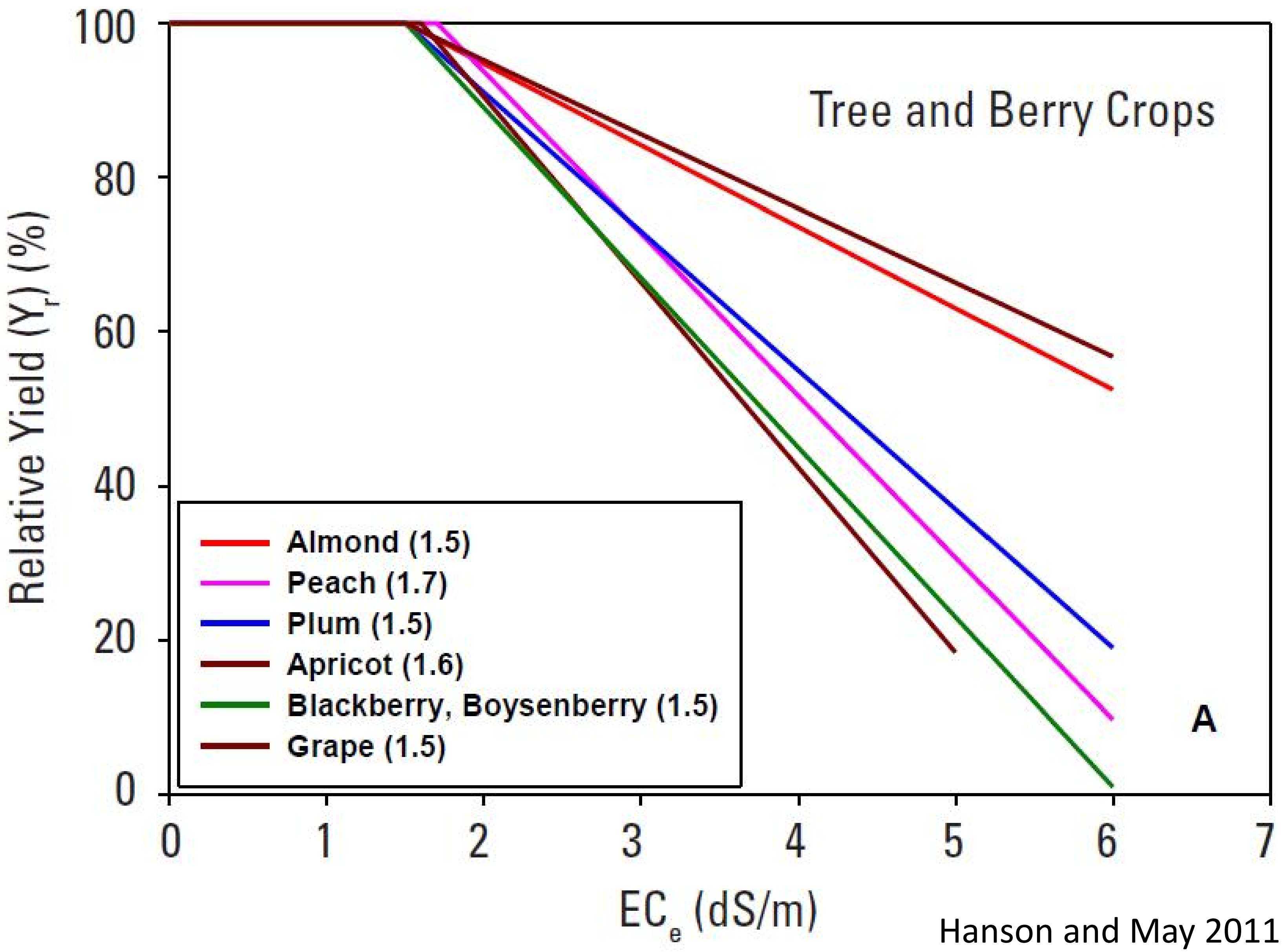


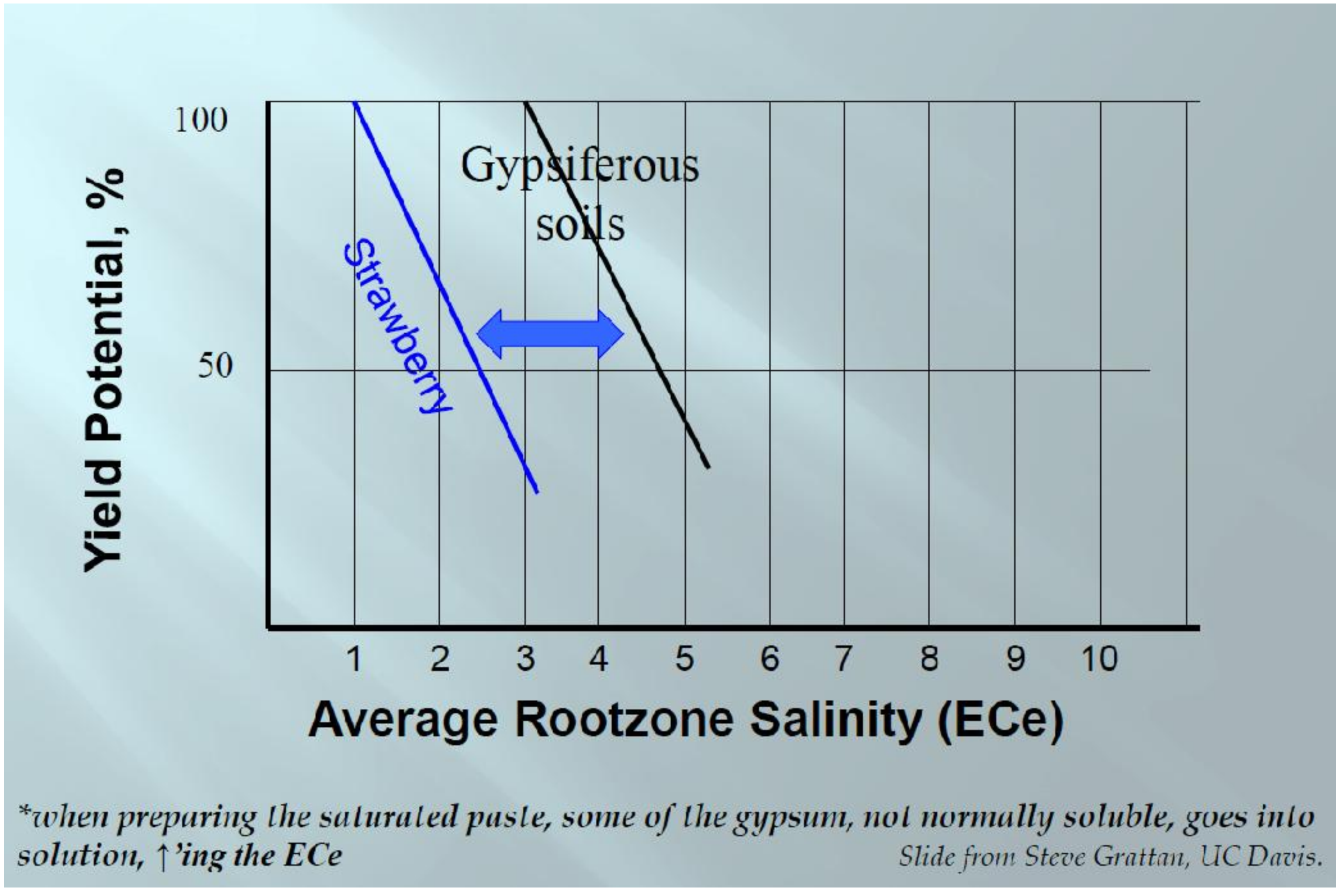
Hanson and May 2011

Salinity Effects on Tree and Berry Crops

	Percent Yield Reduction					
	0%		10%		25%	
	ECe	ECw	ECe	ECw	ECe	ECw
	------------------------------- dS/m* -------------------------------					
Apple	1.7	1.0	2.3	1.6	3.3	2.2
Apricot	1.6	1.1	2.0	1.3	2.6	1.8
Avocado	1.3	0.9	1.8	1.2	2.5	1.7
Blackberry	1.5	1.0	2.0	1.3	2.6	1.8
Fig	2.7	1.8	3.8	2.6	5.5	3.7
Grape	1.5	1.0	2.5	1.7	4.1	2.7
Grapefruit	1.8	1.2	2.4	1.6	3.4	2.2
Lemon	1.7	1.1	2.3	1.6	3.3	2.2
Olive	2.7	1.8	3.8	2.6	5.5	3.7
Orange	1.7	1.1	2.3	1.6	3.2	2.2
Peach	1.7	1.1	2.2	1.4	2.9	1.9
Pear	1.7	1.0	2.3	1.6	3.3	2.2
Plum	1.5	1.0	2.1	1.4	2.9	1.9
Raspberry	1.0	0.7	1.4	1.0	2.1	1.4
Strawberry	1.0	0.7	1.3	0.9	1.8	1.2

* 1 dS/m = 640 ppm

Salt tolerance is often higher in water or soil dominated by gypsum



Specific Ion Toxicity

Specific Ion Toxicity	Units	Degree of Restriction on Use[1] No restriction	Slight to Moderate	Severe
Sodium (Na^+)		***------ Trees, Vines, and other Sensitive Crops -------***		
surface irrigation	mg/L	< 70	70 - 200	> 200
sprinkler irrigation	mg/L	< 70	> 70	
		-------------- Vegetables --------------------		
sprinkler irrigation	mg/L	< 115	115-460	> 460
Chloride (Cl^-)				
		------ Trees, Vines, and other Sensitive Crops -------		
surface irrigation	mg/L	< 140	140-350	> 350
sprinkler irrigation	mg/L	< 100	> 100	
		-------------- Vegetables --------------------		
sprinkler irrigation	mg/L	< 175	175-700	> 700
		-------------- All crops --------------------		
Boron (B) [2]	mg/L	< 0.7	0.7-3	> 3
Bicarbonate (HCO_3^-)[1]	meq/L	< 1.5	1.5-7.5	>7.5

1. Adapted from FAO irrigation and drainage paper 29, 1985

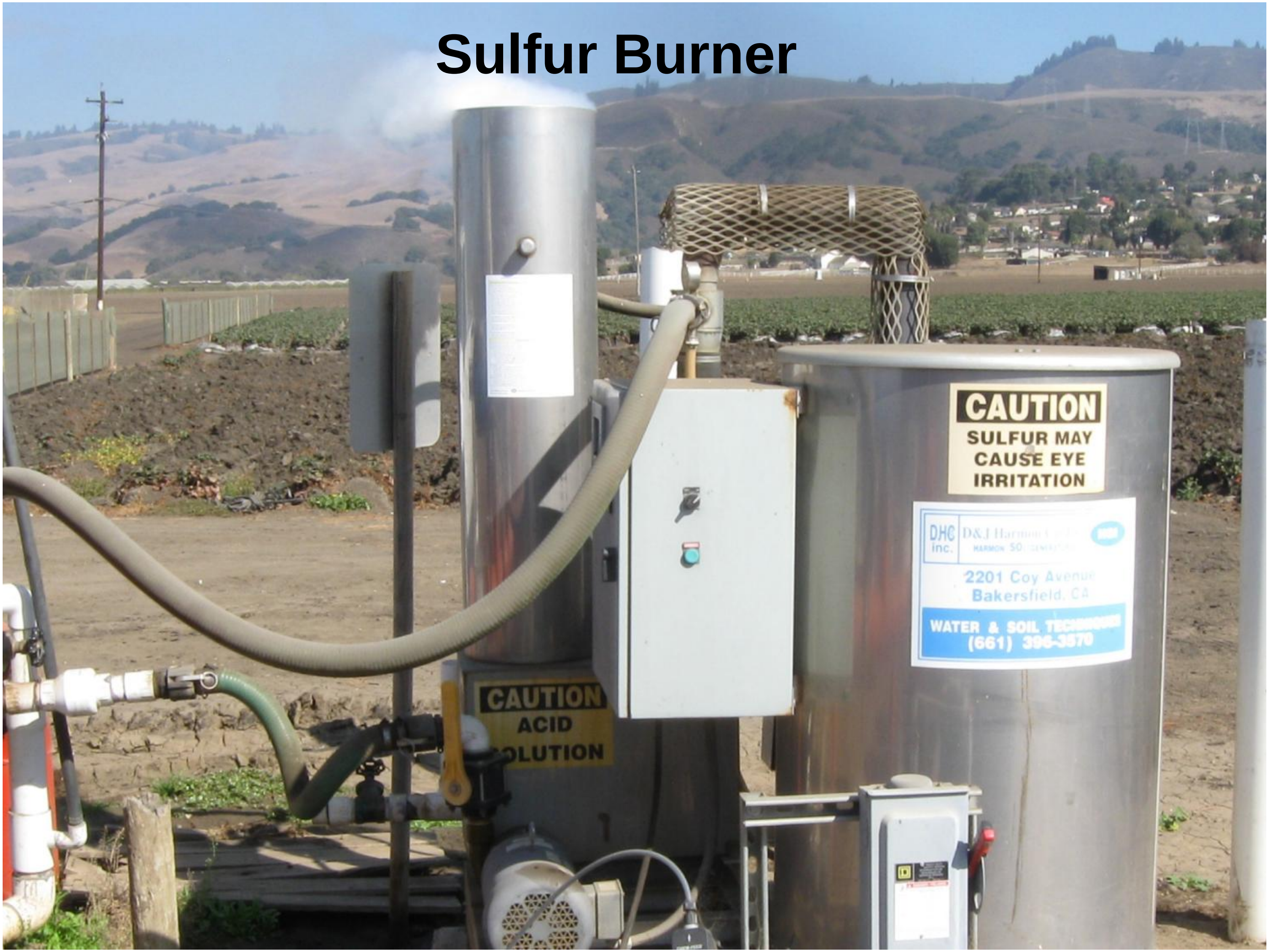
2. sprinkler irrigation only

Guidelines for water suitability of grapes

Constituent	Units	None	Slight to Moderate	Severe
pH		< 6.5	6.5 -8.4	> 8.4
ECw	dS/m	<1	1.0 - 2.7	> 2.7
Sodium (Na^+)	meq/L	< 20	--	--
	ppm	<460	--	--
Chloride (Cl^-)	meq/L	<4	4 - 15	> 15
	ppm	< 140	140 - 525	> 525
Boron (B)	ppm	< 1	1 - 3	> 3
Bicarbonate (HCO_3^-)	meq/L	< 1.5	1.5 - 7.5	> 7.5
	ppm	< 92	92 - 458	> 458

Adapted from Neja et al. 1978

Sulfur Burner



Are there potential infiltration problems?

SAR	Degree of Restriction on Use[1] No restriction	Slight to Moderate	Severe
	------ EC of irrigation water (dS/m) -------		
0-3	> 0.7	0.7-0.2	<0.2
3-6	>1.2	1.2-0.3	<0.3
6-12	>*1.9*	1.9-0.5	<0.5
12-20	>2.9	2.9-1.3	<1.3
20-40	>5.0	5.0-2.9	<2.9

1. Adapted from FAO irrigation and drainage paper 29, 1985

Gypsum Injection (Adds $CaSO_4$)

Potential clogging problems for drip and micro-sprinklers?

		Degree fo Restriction on Use[1]		
Potential Problem	**Units**	**None**	**Slight to Moderate**	**Severe**
Physical				
Suspended Solids	mg/L[2]	< 50	50 - 100	> 100
Chemical				
Dissolved Solids	mg/L	< 500	500 - 2000	> 2000
Manganese	mg/L	< 0.1	0.1 - 1.5	> 1.5
Iron	mg/L	< 0.1	0.1 - 1.6	> 1.6
Bicarbonate	meq/L	< 2	2- 5	> 5

1. Adapted from FAO irrigation and drainage paper 29, 1985
2. 1 mg/L = 1 ppm

Iron and manganese bacteria on screen filter

Example: Assessing suitability of water for grapes

Example: Assessing Suitability of Water for Irrigation

Constituent	Concentration	
	ppm	meq/L
----------- Cations ------------		
Na	171	7.4
Ca	309	15.5
Mg	134	11.2
NH_4	0	0.0
K	6	0.2
----------- Anions ------------		
Cl	210	6.0
SO_4	930	19.4
CO_3 ($CaCO_3$)	0	0.0
HCO_3	340	5.6
NO_3	190	3.1
B	0.3	
Fe	0.11	
Mn	0.01	
pH	7.4	
EC (dS/m)	2.8	

Cations = 34.3 meq/L

Anions = 34.1 meq/L

1. Sum of cations = sum of anions

2. TDS = 2290 mg/L
Estimated EC = 2290/800
= 2.9 dS/m

Potential plugging in drip from bicarbonate and iron

Bulk EC above yield loss threshold for grapes

Example: Assessing Suitability of Water for Irrigation

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----------- Cations ------------		
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SAR = 2.0, SARadj = 2.6, no infiltration limitations

Potential salt damage with sprinklers

Potentially form precipitates with calcium containing fertilizers (CAN17)

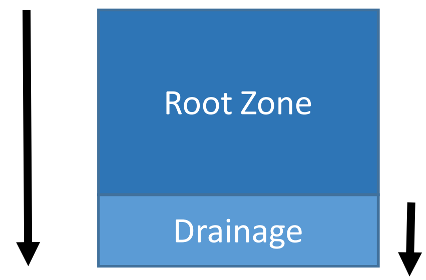
Nitrate-N conc. = 43 ppm (10 lbs N/acre-inch)

What is a leaching fraction (LF)?

Water applied to prevent the build up of salts in the soil.

$$\mathrm{LF} = \frac{\textit{depth of water draining below root zone}}{\textit{depth of applied water}}$$

Applied Water
= rainfall + irrigation – runoff
= 10 inches



Water Draining below Root Zone
= 2 inches

Leaching Fraction = 2 in./10 in. = 0.2 or 20%

How do you determine how much water to apply to attain a desired leaching fraction?

$$Applied\ Water = \frac{ETc}{1 - LF}$$

Example:

If LF = 0.3 (30%) and ET = 15 inches

$$Applied\ Water = \frac{15\ inches}{1-0.3} = 21.4\text{ inches}$$

Leaching Fraction vs Percentage of Crop ET

Leaching Fraction	Applied Water as a Percentage of Crop ET
--------- %	----------
5	105
10	111
15	118
20	125
25	133
30	143
35	154
40	167
50	200
60	250
70	333
80	500

$$LF = \frac{D}{ET + D}$$

Assumptions in estimating a leaching fraction:

AW = ETc/(1-.15)

AW = ETc/(.85)

AW = 1.17ETc

AW = 117%ETc

⬇

D = 77% ETc

⬇

D = 47% ETc

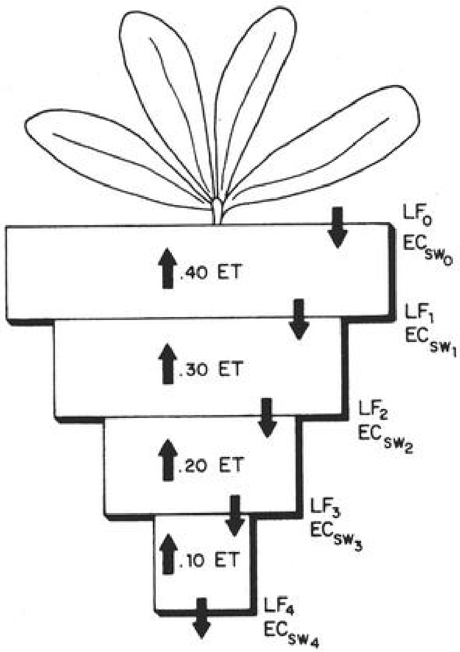
⬇

D = 27% ETc

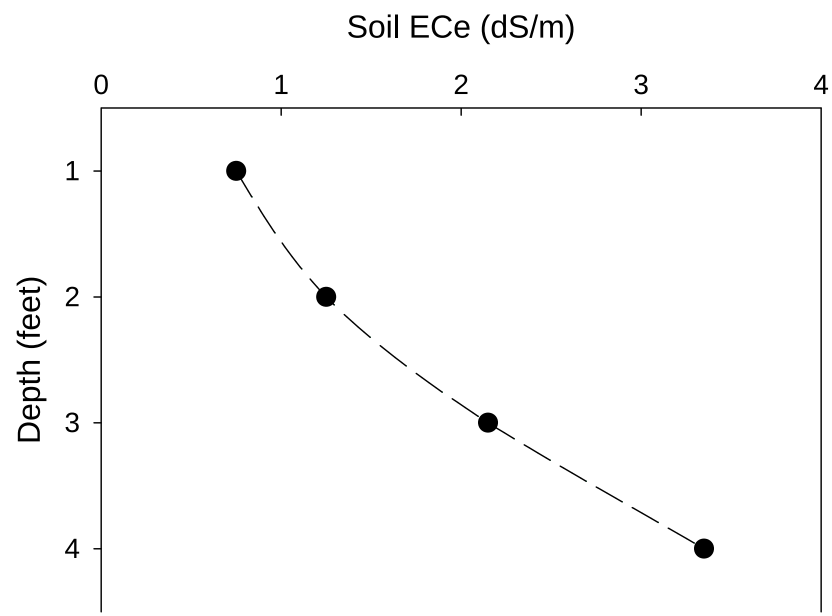
⬇

D = 17% ETc

⬇



LR = 15%, ECw = 1



Estimating the Leaching Requirement

$$LR = \frac{ECw * 100}{(5 * ECe) - ECw}$$

Example:
Water ECw = 2.8 dS/m
Yield Threshold (95%): ECe = 2.0 dS/m

$$\frac{2.8\, ds/m * 100}{(5 * 2.0\, ds/m) - 2.8} = 39\%$$

Estimating the Leaching Requirement

Soil Salinity (EC_e) in dS/m \ Salinity of Irrigation Water (EC_w) in dS/m	0.2	0.5	0.7	1	1.3	1.5	2	2.5	3	4	5	6	7
0.5	9	25	39	--	--	--	--	--	--	--	--	--	--
1	4	11	16	25	35	43	--	--	--	--	--	--	--
1.5	3	7	10	15	21	25	36	50	--	--	--	--	--
2	2	5	8	11	15	18	25	33	43	--	--	--	--
2.5	2	4	6	9	12	14	19	25	32	47	--	--	--
3	1	3	5	7	9	11	15	20	25	36	50	--	--
3.5	1	3	4	6	8	9	13	17	21	30	40	52	--
4	1	3	4	5	7	8	11	14	18	25	33	43	54
4.5	1	2	3	5	6	7	10	13	15	22	29	36	45
5	1	2	3	4	5	6	9	11	14	19	25	32	39
5.5	1	2	3	4	5	6	8	10	12	17	22	28	34
6	1	2	2	3	5	5	7	9	11	15	20	25	30
6.5	1	2	2	3	4	5	7	8	10	14	18	23	27
7	1	1	2	3	4	4	6	8	9	13	17	21	25

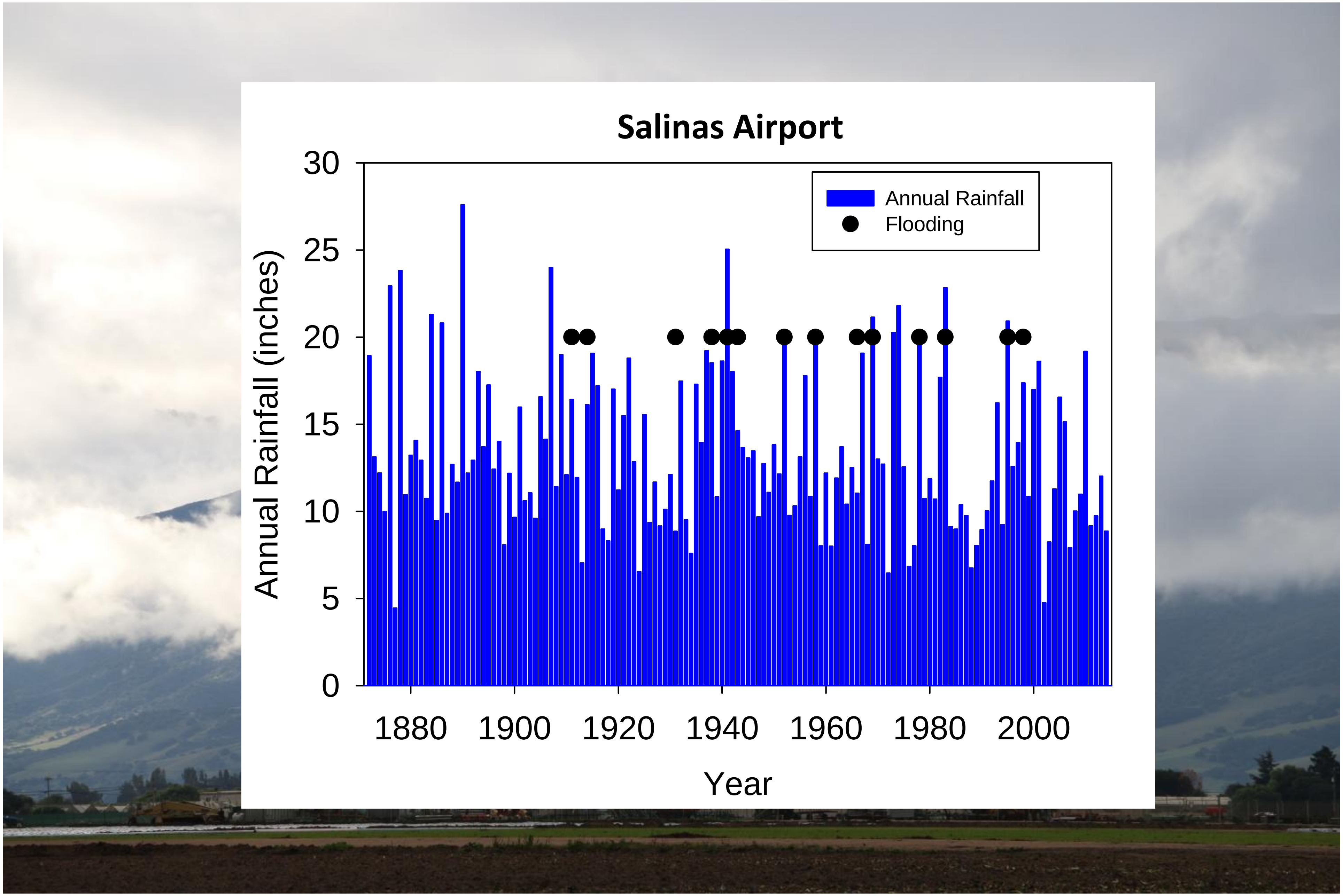
Other considerations to leaching:

- Need drainage (clay pan, perched water table)
- Leads to the leaching of nutrients
- Make most of winter rain and pre-irrigations

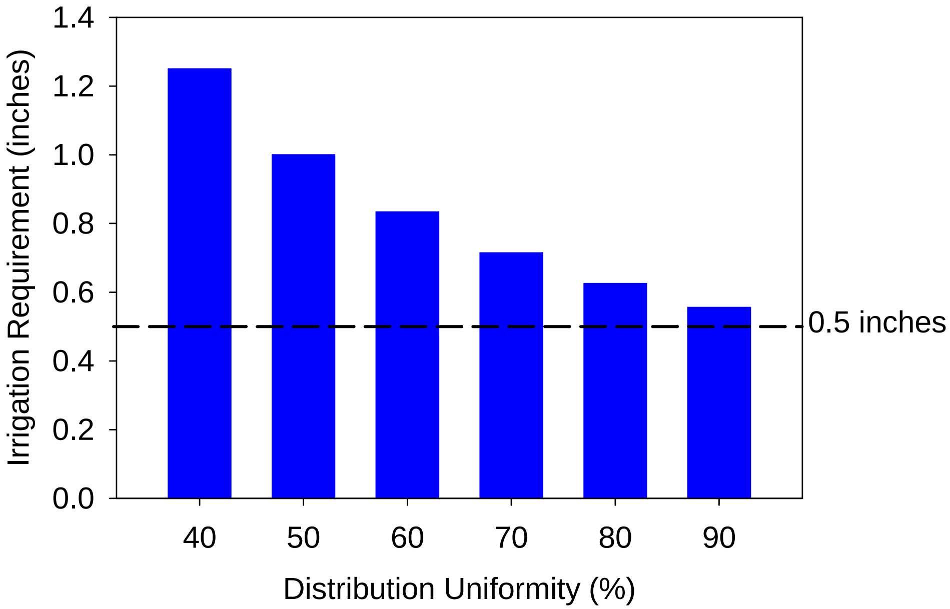
Enhance Infiltration and Drainage

- **Tile Drainage**
- **Soil amendments**
- **Cover crops**
- **Deep tillage**

Infiltrate Winter Rain



Improving application uniformity can improve salinity control



Field Assessment of Leaching Fraction

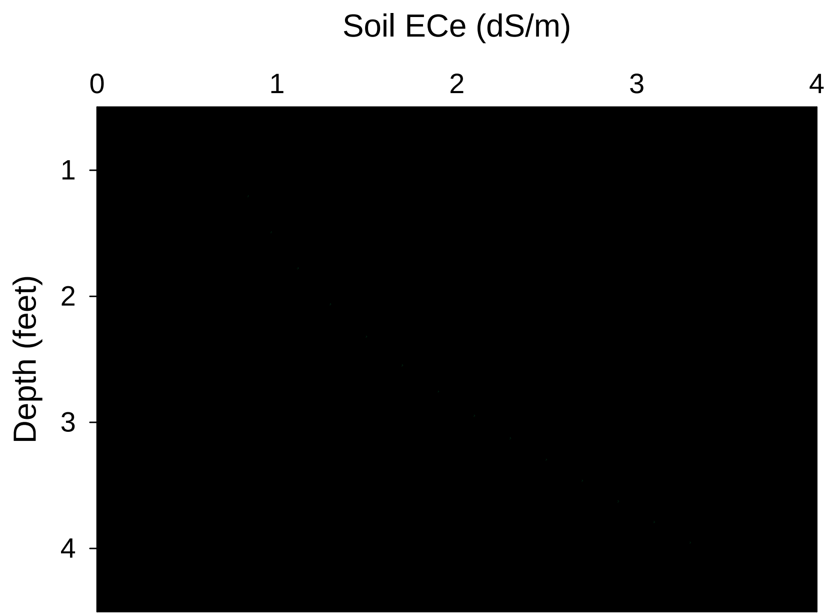
1. Sample soil from 3 to 4 layers of depth in root zone
2. Measure ECe of soil from each layer
3. Calculate the average ECe and compare to yield threshold ECe
4. Measure irrigation water salinity (ECw)
5. Calculate the actual Leaching Fraction

Example:
Water ECw = 1.0 dS/m
Average ECe = 2.0 dS/m

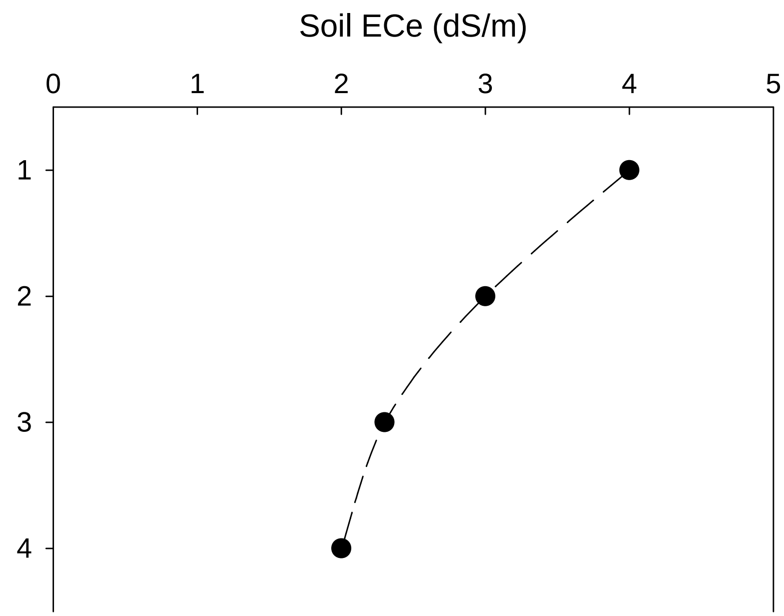
$$\frac{1.0\ ds/m\ * 100}{(5 * 2.0\ ds/m) - 1.0} = 11\%$$

Field Assessment of Leaching Fraction

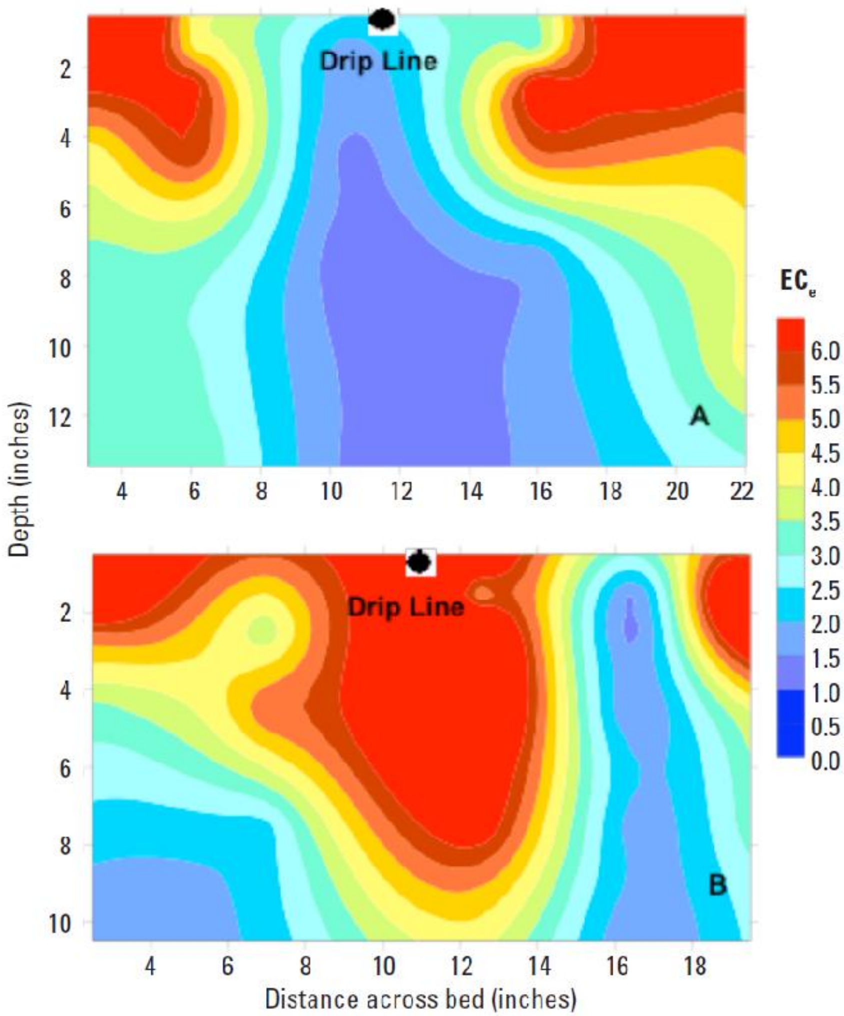
Adequate Leaching



Inadequate Leaching



Assessing salinity under drip can be challenging



Hanson and May 2011

Summary

1. Salinity affects crop growth through osmotic effects and specific ion toxicity.
2. All dissolved ions contribute to salinity in water.
3. EC of a saturated paste is the measurement correlated with the salt tolerance of crops.
4. Leaching fractions are needed to prevent soil salinity from increasing beyond the threshold for crop yield loss.
5. Improving the application uniformity of an irrigation system can help improve salt management and reduce nitrate leaching losses.

Managing Salinity under Drought Conditions

- Less rainfall, higher ET, ground water may be saltier
- Deficit irrigation may increase salt build up in soil
- Use an appropriate leaching fraction
- Credit all rainfall, pre-irrigation and germination water
- Maximize application uniformity
- Irrigate more frequently
- Monitor soil and water salinity