Detecting and Mitigating Salinity

Larry A. Stein

Texas A & M AgriLife Extension Service

Water

- **Turgor pressure to expand cells**
- **All contain salt**
- **Key is how much?**
- **And what kind?**

Water moves from a high concentration to a low concentration
Said another way water moves to a higher concentration of salts

Salinity

- Describes dissolved solids in water and soil
- How much
- What kind
- Too much in soil solution; water moves out of the plant
- Less water available to plant

- **Salt:** electrically charged lattice of cations (+) and anions (-) resulting from an acid-base, charge neutralizing reaction.

- **Cations**:
  - Calcium ($Ca2^{+}$)
  - Magnesium $Mg2^{+}$)
  - Sodium (Na^{+})
  - Iron (Fe^{2+} and Fe^{3+})
  - Ammonium (NH^{4+})
- **Anions**:
  - Bicarbonate (HCO_3^{-})
  - Cabonate (CO_3^{2-})
  - Chloride (Cl^{-})
  - Sulfate (SO_4^{2-})
  - Nitrate (NO_3^{-})

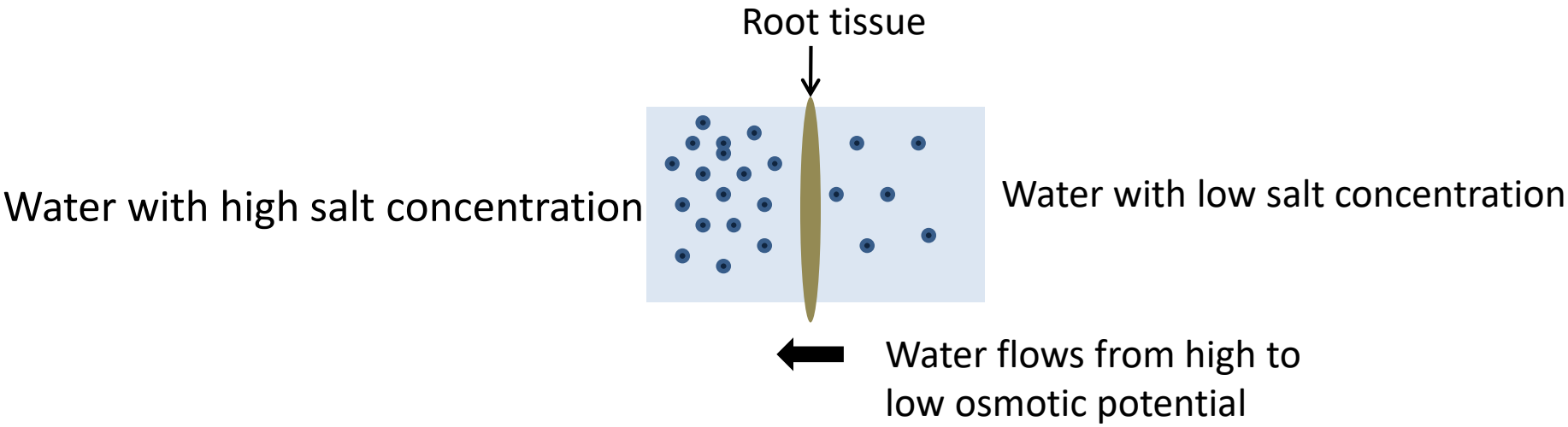
Slide Credits: Scheiner

- $Ca(HCO_3)_2$
- $NaCl_2$
- $MgSO_4$
- $Ca(NO_3)_2$

Salt and Osmotic Potential

All irrigation water contains dissolved salts

- Dissolved salt increases the osmotic (suction) potential
- Water flows from high to low water potential
- The more dissolved salt in soil water, the more difficult it is for roots to extract it (drought stress)



How can salts negatively impact grapevines?

1. Osmotic stress
2. Ion toxicity
3. Impact on soil properties

Measures of Salinity

Soil and Irrigation Water:

1. **Electrical conductivity** (**EC**): pure water will not conduct electricity, but it will with the addition of salt
   - Units: mmho/cm, dS/m
   - EC is a good estimator of the total dissolved salts
2. **Total Dissolved Solids (TDS)** and **Total Soluble Salts (TSS)**
   - **Units:** ppm, mg/L (ppm = mg/L)

- EC can be used to estimate TDS and TSS using the following
- equation:
  - **EC (dS/m) x 640 = TSS or TDS**

Salinity in Irrigation Water

Guidelines for Interpreting Irrigation Suitability for Vineyards

Analysis (Salinity)	No Problem	Increasing Problem	Severe Problem
EC dS/m or mmho/cm	< 1	1.0 to 2.7	>2.7
TDS ppm or mg/L	<640	640 to 1728	>1728

Potential severity is a general guideline and will vary by:

- soil type
- rainfall
- irrigation frequency

Soil Salinity

Guidelines for Interpreting Soil Suitability for Vineyards

Analysis (Salinity)	No Problem	Increasing Problem	Severe Problem
EC dS/m or mmho/cm	1.5 to 2.5	2.5 to 4.0	4.0 to 7.0
TDS ppm or mg/L	960 to 1600	1600 to 2560	2560 to 5600

10 to 25% yield reduction expected

25 to 50% yield reduction expected

Ion Toxicity

Guidelines for Interpreting Irrigation Suitability for Vineyards

Analysis (Salinity)	No Problem	Increasing Problem	Severe Problem
Sodium ppm Meq/L	<20 <460		
Chloride ppm Meq/L	<140 <4	140 to 525 4 to 15	>525 >15
Boron ppm	<1	1-3	>3

Ion Toxicity

Guidelines for Interpreting Soil Suitability for Vineyards

Analysis (Salinity)	No Problem	Increasing Problem	Severe Problem
Sodium ppm Meq/L		>690 >30	
Chloride ppm Meq/L	<350 <10	350 to 1060 10 to 30	>1060 >30
Boron ppm	<1	1 to 3	>3

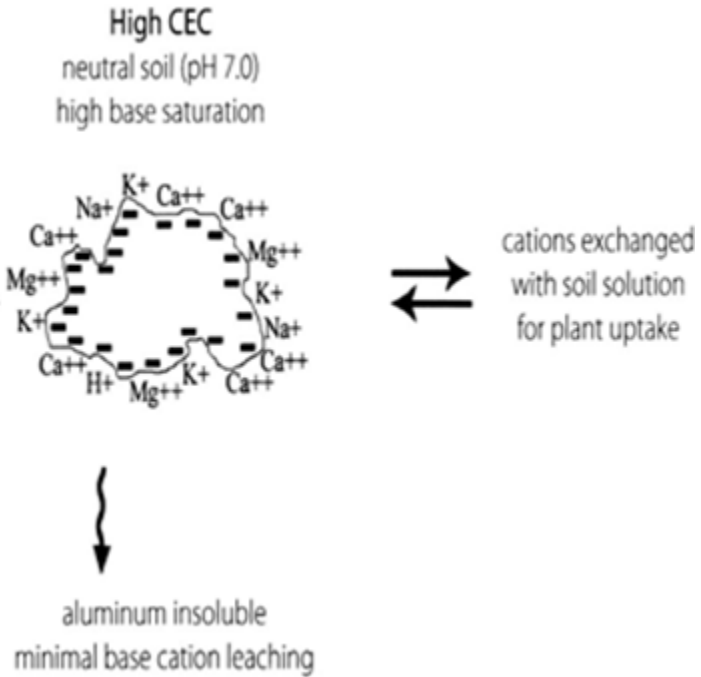
Toxicity symptoms often include marginal leaf burn and stunted growth. If you suspect toxicity take a tissue sample.

Sodium Hazard

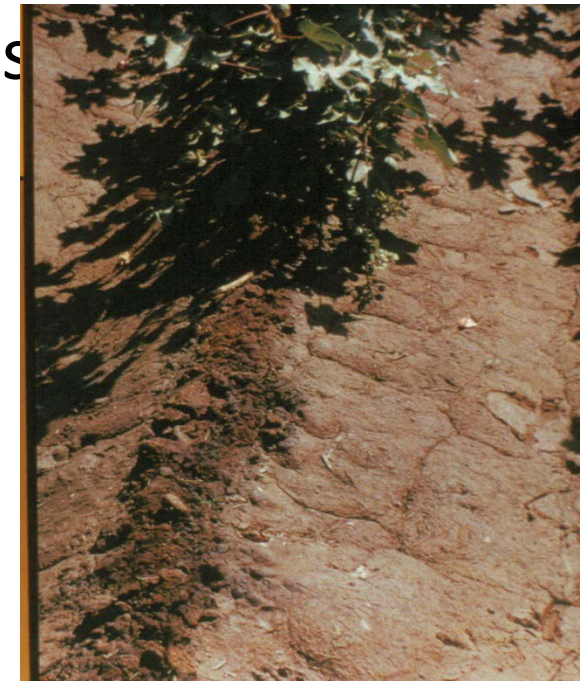
- Cations are adsorbed to soil based on the type of ion (attraction) and concentration present:

strong attraction weak attraction

$$Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} = NH^{4+} > Na^{+}$$



- Significant sodium adsorption can result in loss of
- soil structure (particularly clay soils
- hard compacted soil
- reduced water infiltration
- reduced root growth



- Measured as:
- **Exchangeable sodium percentage (ESP)**
- **Sodium adsorportion ratio (SAR)**

- **Sodium adsorption ratio (SAR)**

- ratio of activity of sodium to calcium and magnesium
- calcium and magnesium compete with sodium for exchange sites

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++}+Mg^{++})/2}}$$

Guidelines for Interpreting Irrigation Suitability for Vineyards

Analysis	No Problem	Increasing Problem	Severe Problem
SAR	< 6	6 to 9	>9

***High levels of carbonate and bicarbonate increase sodium hazard of water**

- **Exchangeable sodium percentage (ESP)**

- Percentage of CEC in soil occupied by sodium

Analysis	No Problem	Increasing Problem	Severe Problem
ESP	<10	10 to 15	>15

When should you start looking for other

Water Source =Well Water Use =Irrigation

Parameter analyzed		Results	Units	Method	V. Limiting	Limiting	Acceptable
Calcium (Ca)		608	ppm	ICP		*****	
Magnesium (Mg)		221	ppm	ICP		*****	
Sodium (Na)		1432	ppm	ICP	*****		
Potassium (K)		10	ppm	ICP			*****
Boron (B)	<	0.01	ppm	ICP			*****
Carbonate (CO_3)		0	ppm	Titr.			*****
Bicarbonate (HCO_3)		293	ppm	Titr.			*****
Sulfate (SO_4 calculated from total S)		1591	ppm	ICP	*****		
Chloride (Cl^-)		2277	ppm	Titr.	*****		
Nitrate-N (NO_3-N)		0.18	ppm	Cd-red.			*****
Phosphorus (P)	<	0.01	ppm	ICP			*****
pH		6.74		ISE			*****
Conductivity		8170	umhos/cm	Cond.	*****		
Hardness		141	grains CaCO3/gallon	Calc.		*****	
Hardness		2428	ppm CaC03	Calc.		*****	
Alkalinity		240	ppm CaC03	Calc.			*****
Total Dissolved Salts (TDS)		6433	ppm	Calc.	*****		
SAR		12.6		Calc.		*****	
Iron (Fe)		0.25	ppm	ICP			*****
Zinc (Zn)		0.05	ppm	ICP			*****
Copper (Cu)	<	0.01	ppm	ICP			*****
Manganese (Mn)		4.08	ppm	ICP		*****	
Arsenic (As)							

Irrigation Water pH & Alkalinity

- pH—measure of the H+ ions in the water
- Alkalinity—measure of the water's ability to neutralize acidity
  - Amount of carbonates, bicarbonates, hydroxides
  - Measurement by ppm calcium carbonate ($CaCO_3$)
- pH test alone does not assess alkalinity
  - High alkalinity = basic pH
  - Basic pH may not mean high alkalinity

Impact of high alkalinity water

- Indicator of high salinity
- Micronutrients (Iron, zinc, manganese, copper) become less available for soil uptake
- Scaling, plugging, stoppage of emitters
- Hydrolysis of spray solutions

- Acid injection:
- **H+ (from acid) + HCO_3- (in the irrigation water) → CO_2 + H_2O**
- infuric acid

Acid injection requirement

Determined by:

- total carbonates
- pH of water
- acid type

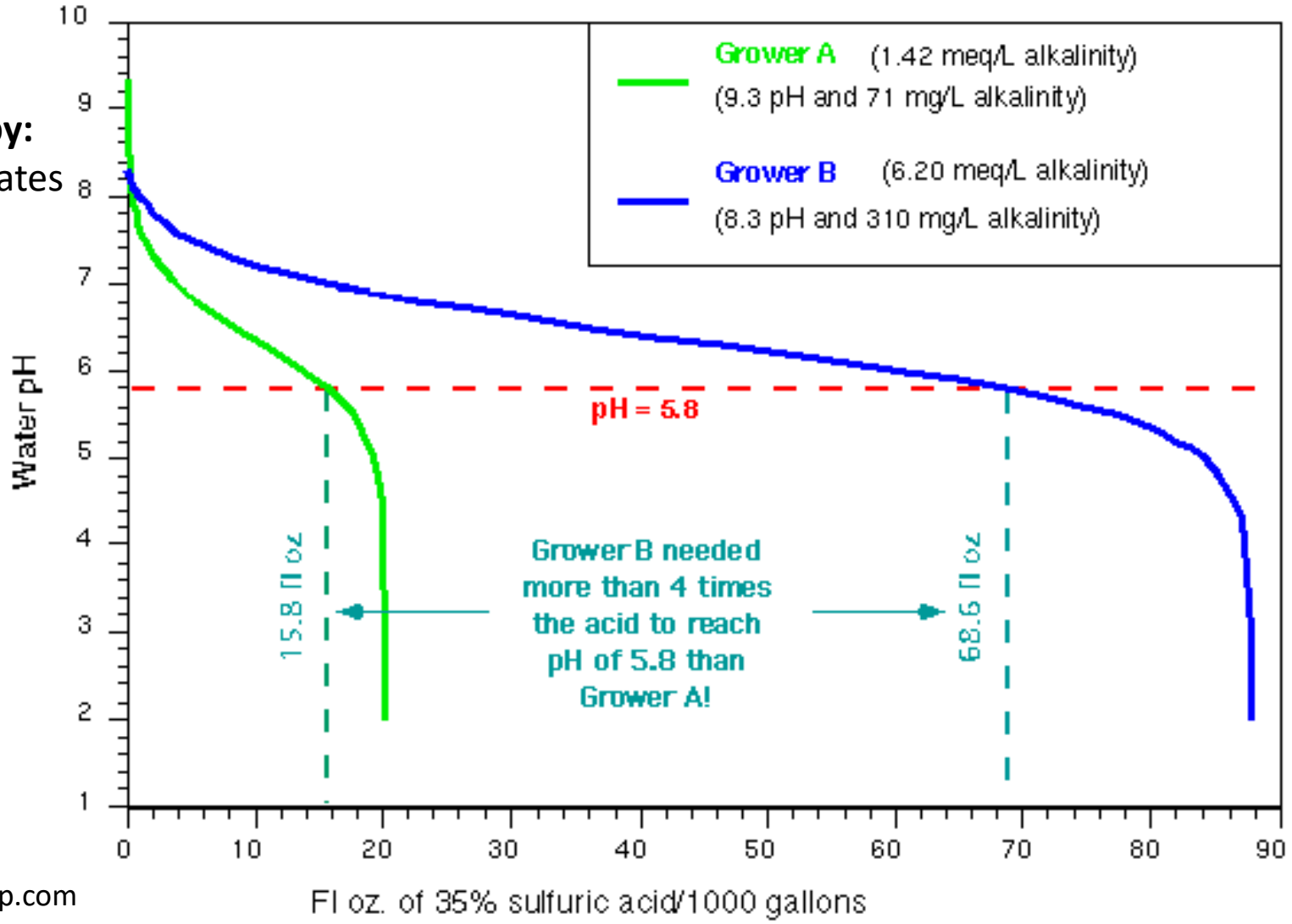
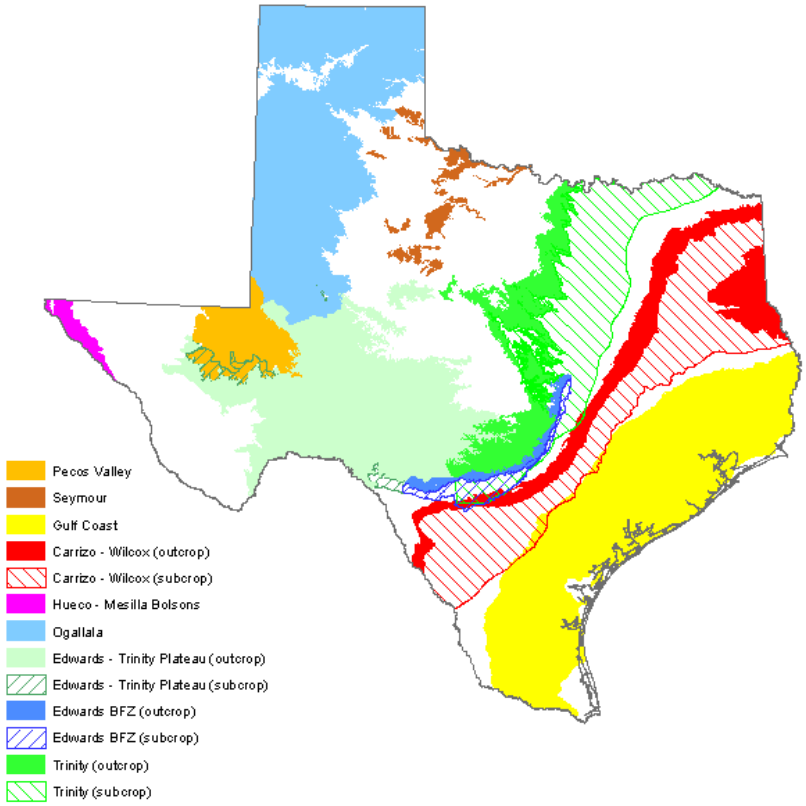


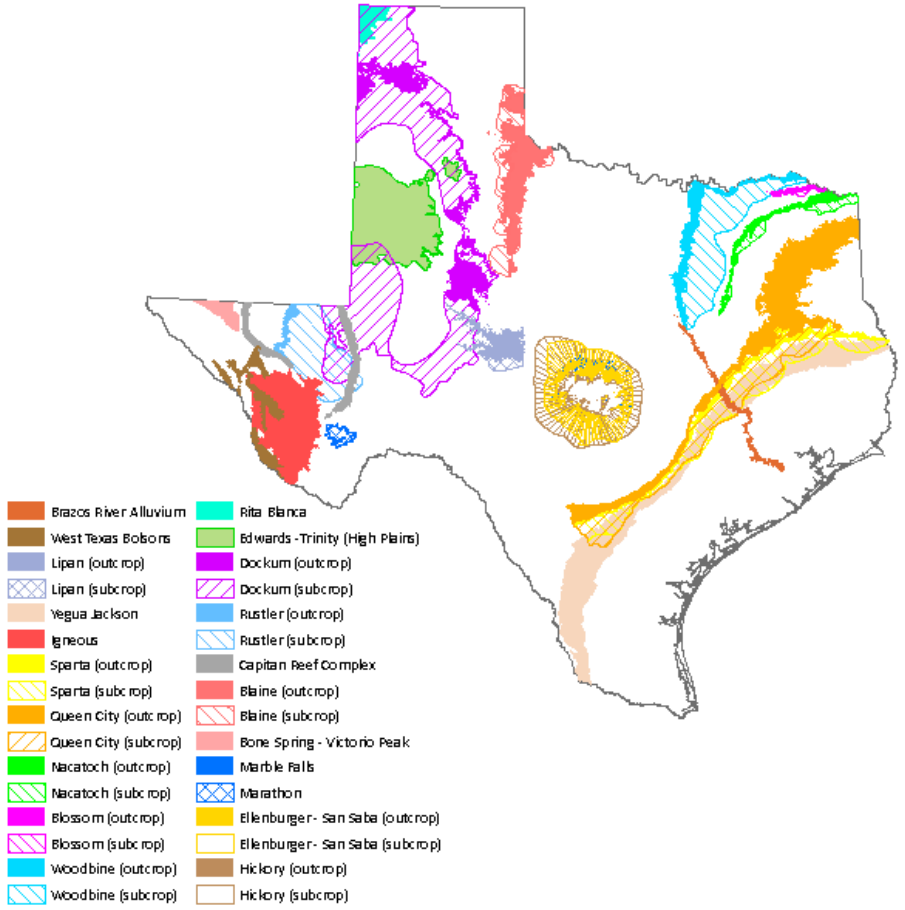
Figure from: Polydrip.com

Other salts found in Texas wells

- **Sulfates—(SO4): not a serious limitation**
  - rotten egg smell if sulfate-reducing bacteria convert hydrogen sulfide gas
  - contributes to salinity hazard
- **Nitrates—(NO3): free plant growth fertilizer**
  - may stimulate growth at wrong time
  - contributes to salinity hazard

Sources of Irrigation Water Vary





Images from: Texas Water Development Board

Predicting Irrigation Water Quality

- **Prior to drilling a well**:
  - Investigate water quality in nearby wells (talk to neighbors in area).
  - Talk to experienced local well driller.
  - Texas Water Development Board ground water database (www.twdb.state.tx.us).
- **Test the water**:
  - Prior to installation of irrigation system.
  - Every 1-2 years (particularly following drought).
  - Use lab qualified to test irrigation water or other intended use.

Slide Credit: Scheiner

Irrigation Water and Soil Testing

- What information should you be interested in?

1. Total concentration of soluble salts (TDS, TSS, EC)
2. Relative proportion of sodium to other cations (SAR)
3. Bicarbonate concentration as related to the calcium, and magnesium
4. Concentration of specific elements and compounds

- When should you test your irrigation water?
- The time of year that you will be irrigating most (summer)

Interpretation of Results

- What are the offending salts?
  - Sodium, chloride vs. sulfates, carbonates
- What is the soil type for your vineyard?
  - Coarse textured soils lower risk, more readily leached
- How much rainfall occurs in your region?
  - Occasional, supplemental use vs. depend

Annual rainfall (30 year avg)

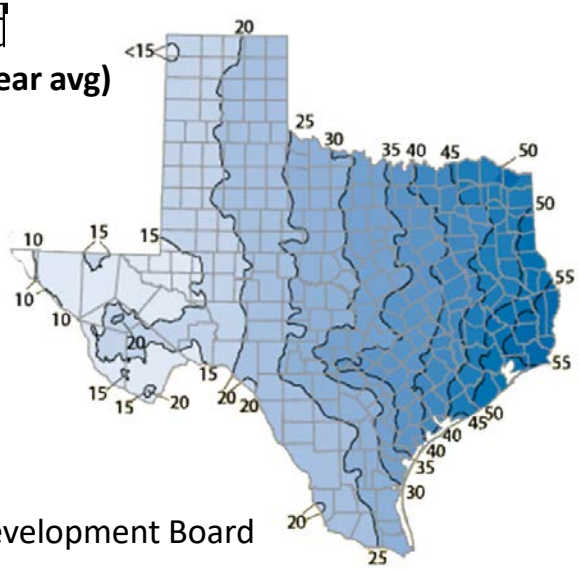


Image from: Texas Water Development Board

Mitigating Salinity Problems

- Alternate clean water source
- Rootstock selection
- Leaching
- Soil amendments

Rootstocks and Salt Tolerance

- Rootstocks reported to have moderate to good salt
- tolerance:
- Salt Creek
- Dog Ridge
- 1103P
- 140Ru
- St. George

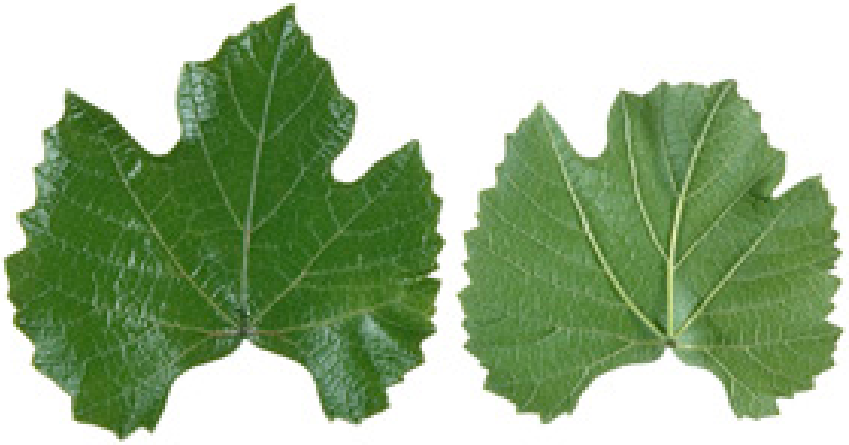


Image from: UC Integrated Viticulture

Leaching

- Natural rainfall
- Irrigation in excess of vine needs
- Subsurface drainage below root zone
- Addition of soil amendments (Calcium)
- Reclamation should be conducted when soil salts reach threshold
- Winter months, following significant rainfall is more practical

Leaching Requirement

- **L_r = Leaching requirement (how much water is needed to leach salts)**

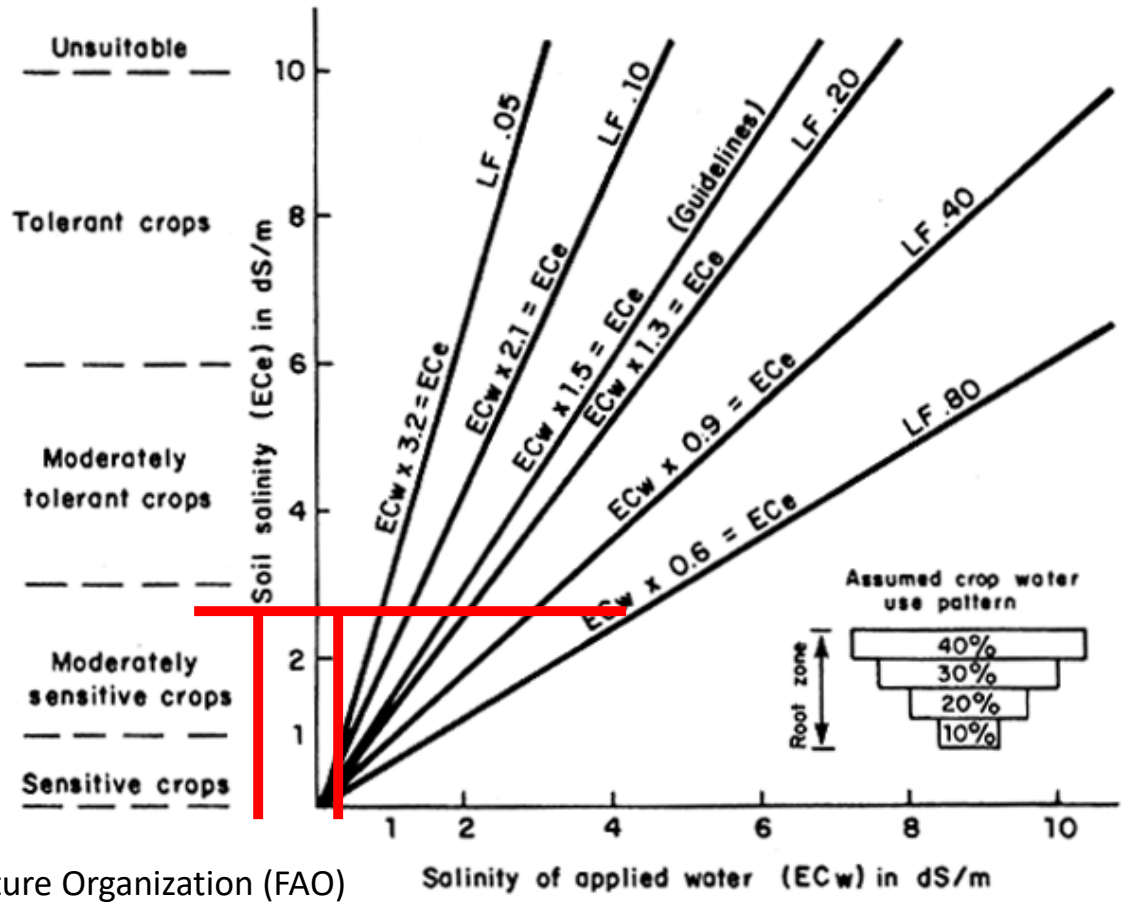


Figure from: Food and Agriculture Organization (FAO)

Gypsum

- Gypsum ($CaSO_4 \cdot 2H_2O$) banded under vine row or injected
- calcium exchanges with sodium on soil exchange sites
- sodium can be leached beyond rooting zone

Gypsum Rate Based on Exchangeable Sodium Percentage

Soil Texture	Exchangeable Sodium Percentage					
	10	15	20	30	40	50
	Gypsum (tons per acre)					
Coarse	1.1	1.7	2.3	3.4	4.6	5.7
Medium	1.9	2.9	3.8	5.7	7.7	9.6
Fine	2.7	4.0	5.4	8.0	10.7	9.6

Table from: Arizona Cooperative Extension (AZ 1413)

Other Soil Amendments for Correcting Saline and Saline-Sodic Soils

Table 2. Summary of conditions appropriate for various soil additives.

Material	Soil pH		Comments
	<7.0	>7.0	
Acids	NO	YES*	Only effective in calcareous soils (*calcareous soils usually have pH>8.0)
Gypsum	YES	YES	Will not change soil pH
Lime	YES	NO	Raises soil pH; not soluble in higher pH soils
$CaSO_4$	YES	YES	Dissolves more slowly than gypsum; will not prevent surface crusting
$CaCl_2$	YES	YES	Can raise soil salinity to unacceptable levels
$Ca(NO_3)_2$	YES	YES	Can raise soil salinity to unacceptable levels if used as a Ca source

The University of Arizona Cooperative Ex

Table from: Arizona Cooperative Extension (AZ 1413)

Other Strategies to Improve Soil Structure

- Cover cropping
- Organic matter
- Mulch


May have to install a drainage ditch or tile to remove excess water and salt

Drastic measures may be required

- Dig out clay lens and mix with another soil to improve drainage

Reclamation efforts are often directed at improving soil drainage

- If the soil drains, there may not be a salinity problem


Manures
High salt content
Can tie up iron and zinc

Sodium in Wine

- How do sodium and chloride affect the flavor of wine?
- contribute flavors that are described as soapy and salty

- Detection threshold of sodium in wine
- White wine: 1.1 g/L
- Red wine: 1.3 g/L