Understanding the Effects of Salinity on Plant Performance

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Salinization

- **When the concentration of soluble salts in the root zone is high enough to impede optimum growth and yield…..**

Why do we have salinization problems…..

Coastal Range:

- is sedimentary marine formation
  - sodium, chlorides, boron

Precipitation and weathering

- wash into oceans and basins
- percolate into the ground
- concentrated by evaporation and lack of drainage
- exacerbated by fertigation

How does salinization harm plants…

- Through the collective action of action of salts in the soil or of specific salts in the plant..

Common Salinizing Constituents

- **Cations = +**
- Na^{+} = Sodium
- Ca^{2+} = Calcium
- Mg^{2+} = Magnesium
- K^{+} = Potassium

- **Anions = -**
- Cl^{-} = Chloride
- SO_4^{-} = Sulfate
- HCO_3^{-} = Bicarbonate
- CO_3^{2-} = Carbonate
  - » pH > 8

Boron = micronutrient

Specific Salts

- **Cations = +**
- Na^+ = Sodium

- **Anions = -**
- Cl^- = Chloride

Boron = micronutrient

Salinity Units of Concentration

- **<u>Weight Basis</u>**
- **1 ppm**
- **1 mg/l**
- **1 mg/kg**
- **1% = 10,000 ppm**

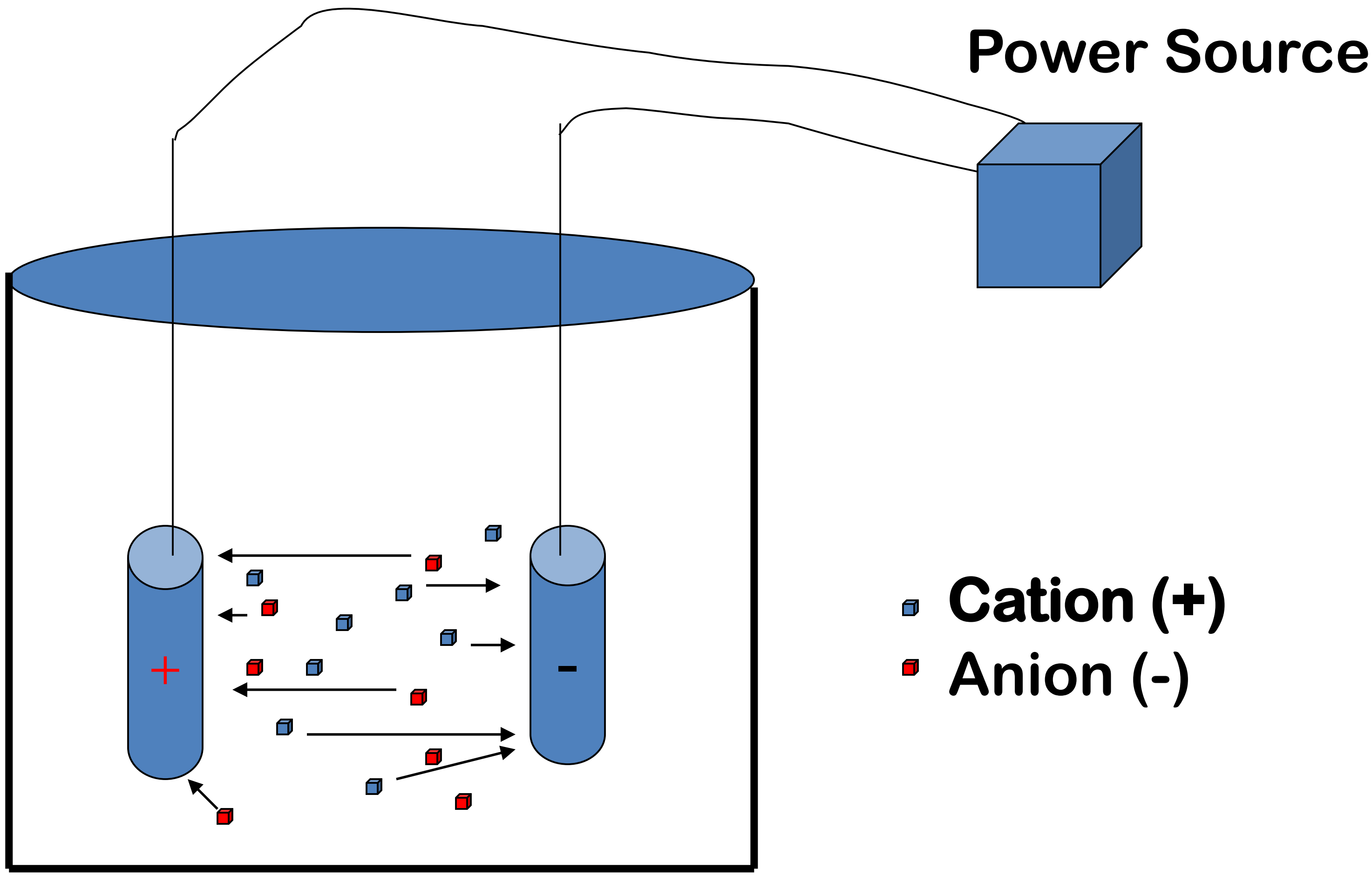
- **<u>Volume Basis</u>**
- **mg/l**
- **meq/l**
- **1mmol$_c$ /l = 1 meq/l**
  - **Systeme International d'Unites (SI)**

Total dissolved solids (TDS) in irrigation and soil water

How is Salinity Measured

- Electrical conductivity (EC)
- Salts dissolve in water (+ or -)
- Charged electrode in water
  - anions and cations migrate = electricity
- Water conducts electricity
- Electrical conductivity meter measures it

Electrical Conductivity




WTW
LF 318
15.83
nLF
TP
mS/cm
µS/cm
AUS
OFF
Conductivity Meter

Salinity Damage has two forms …

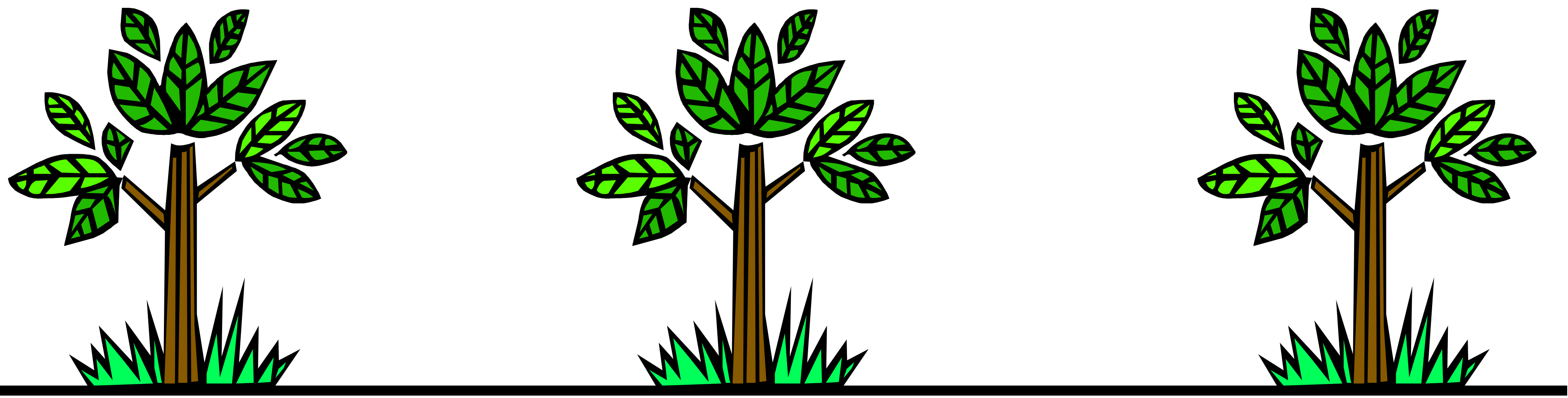
- **Osmotic Effects:**
  - Ions in soil water increases ability of soil to retain water resulting in less water available to the plant for growth…

Salinity Damage has two forms …

- **Specific Ion Effects:**
  - The specific ion directly damages plant parts, generally leaves….

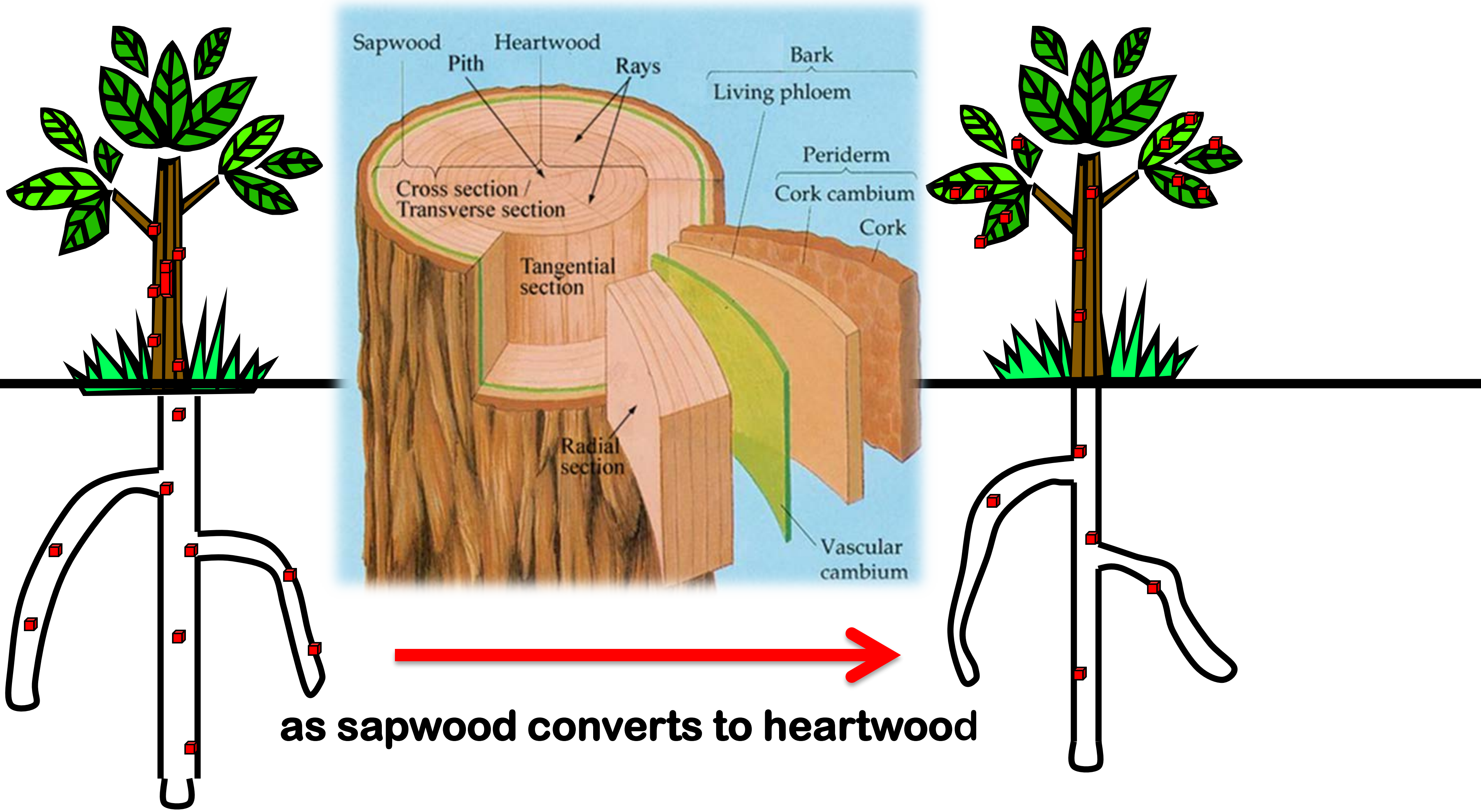

PGI
Well

Tree Sensitivity Increases with Time and Trunk and Root Storage



Early: Osmotic Effects Dominates → **Mature:** Osmotic And Specific Ion Damage → **Older:** Specific ion Damage Dominates

Long Term Effects of Sodium



Summary of Salinity…

- Salinity is a result of geology and time
- Salinity damage has two forms
  - Osmotic
  - Specific ion damage
- Salinity in soil and water will need to be managed..

6/6/2018

Farmer	Eciw (ds/m)	Average Yield 2002 (Tones/ha)	Average ECe (ds/m)	Average Irrigation depth (cm)	Irrigation interval (day)	Applied water (m3/ha)	Soi Textu
Vakili	14.5	1.5	13.14	31.7	50	22190	Si.
Masoomi	22	0	11.51	43	45	34400	L
Mohammadi	24	3.7	10.38	56.7	45	45360	L
Shakeri	11.9	2.2	12.8	24.6	53	17220	L
Barkhordari	8.11	1	15.5	25.75	46	20600	Si
Shateri	13.57	1	15.12	51.5	51	36000	Si

14.88 acre feet/acre

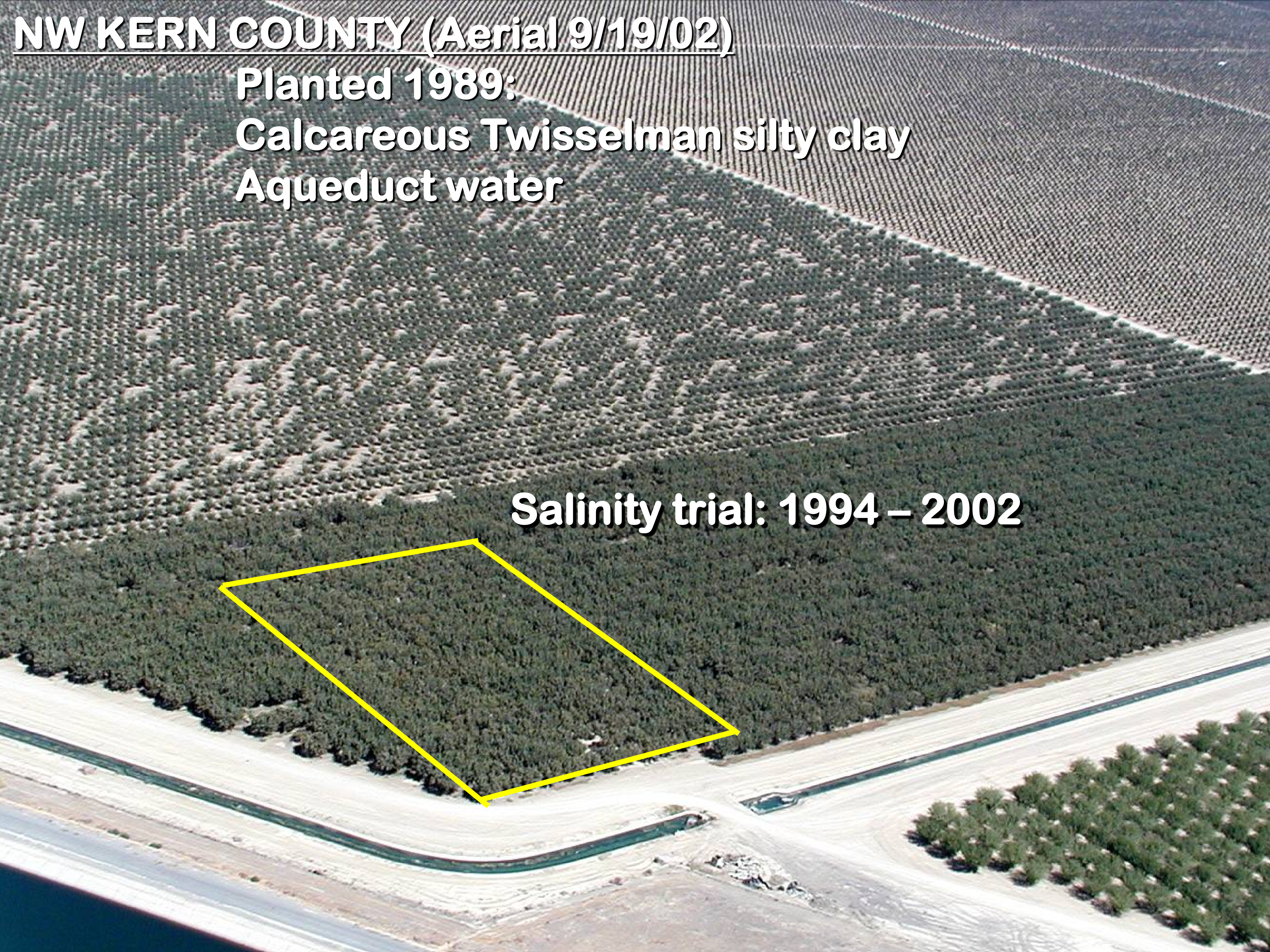
NUTRIENT	CRITICAL VALUES	NORMAL RANGE	GREEN TISSUE	NECROTIC TISSUE
N (%)	2.3	2.5–2.9%	2.3	2.4
P (%)	0.14	0.14–0.17%	0.09	0.09
K (%)	1.0	1.0–2.0%	1.10	0.68
B (ppm)	90	120–250	57	87
Ca (%)	1.3 (?)	1.3–4.0	1.30	1.91
Mg (%)	0.6 (?)	0.6–1.2 (?)	0.59	0.68
Na (ppm)	?	?	6200	12,230
Cl (%)	?	0.1–0.3 ?	1.98	3.43
Mn (ppm)	30	30–80	625,000	60,000
Zn (ppm)	7	10–15	7	6
Cu (ppm)	4	6–10	2.9	2.9

Effects of Salinity

- **Osmotic:**
  - Tree growth poor
- **Specific Ion**
  - Cl and Na
  - absorbed by roots
  - accumulate in leaves
    - Marginal burn

First Salinity Field Trial (1989) 1994 - 2002

- Four Rootstocks:
  - PGI, PGII, UCBI, Atlantica
- Three Salinity Levels
  - 0.75, 4, 8 and 12 dS/m
- Marketable Yield


NW KERN COUNTY (Aerial 9/19/02)
Planted 1989:
Calcareous Twisselman silty clay
Aqueduct water
Salinity trial: 1994 – 2002


6/6/2018

First Orchard Trial Results

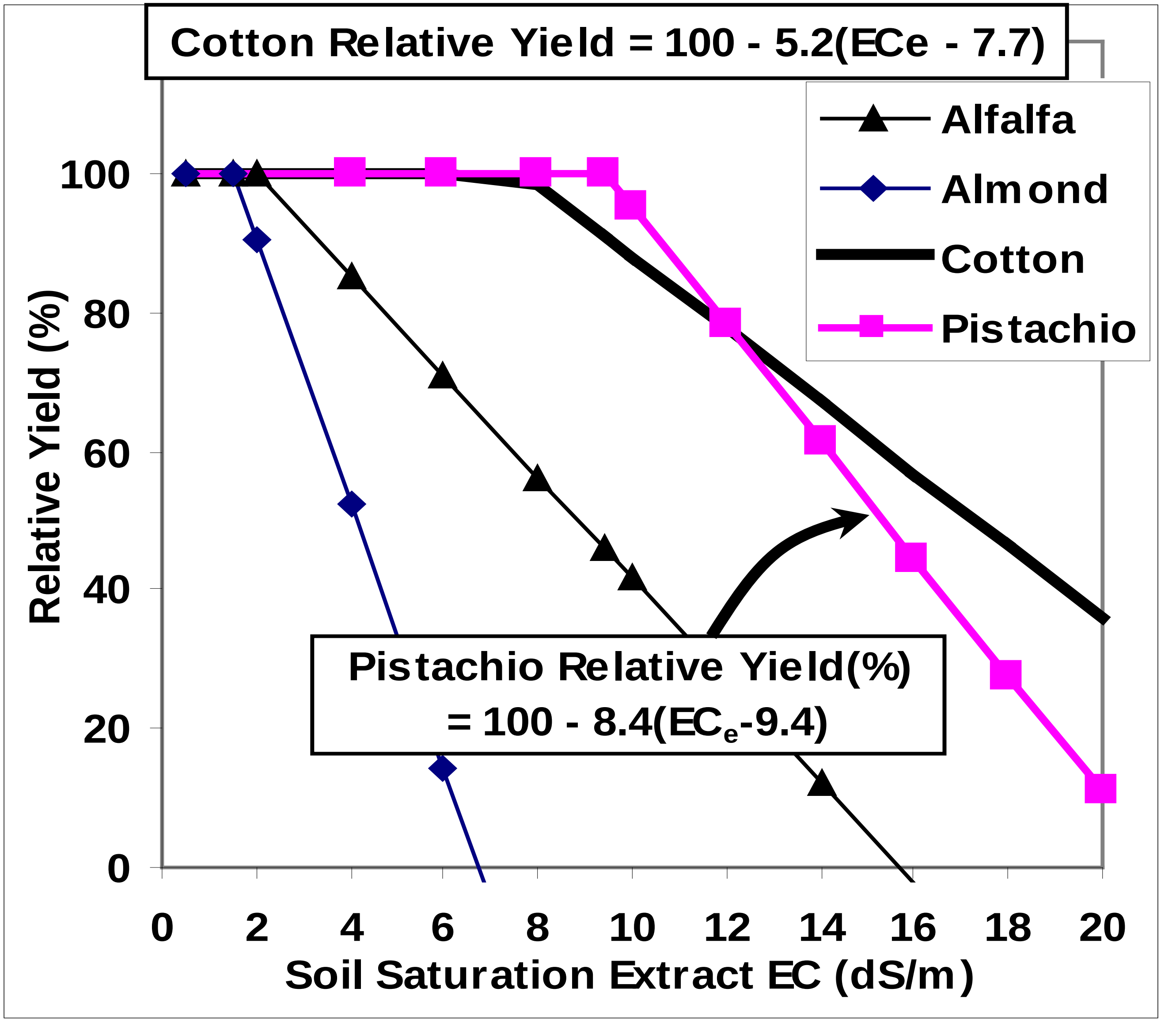
- First Orchard Trial: Marketable Yield
  - Ec_e 8.4 critical value
  - Osmotic effects > specific ion toxicity
  - Rootstock tolerance ranked:
    - % of yield decline from control treatment
    - 8 dS/m
      - PGI > PGII = UCBI > Atlantica
    - 14 dS/m
      - PGI > PGII > UCBI = Atlantica

First First Orchard Trial Problem

- **Established when trial was 5 years old:**
  - **PGI had clear advantage with aqueduct water**

Relative Yield of as a Function of ECe

2004 Pistachio Salinity Threshold



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.

USDA Salinity Laboratory Trial 1999

- Three Rootstocks:
  - PGI, UCBI and Atlantica
- Three Salinity Levels:
  - 4, 8 and 12 dS/m
- Rootstock and Scion Growth
- Ion Distribution

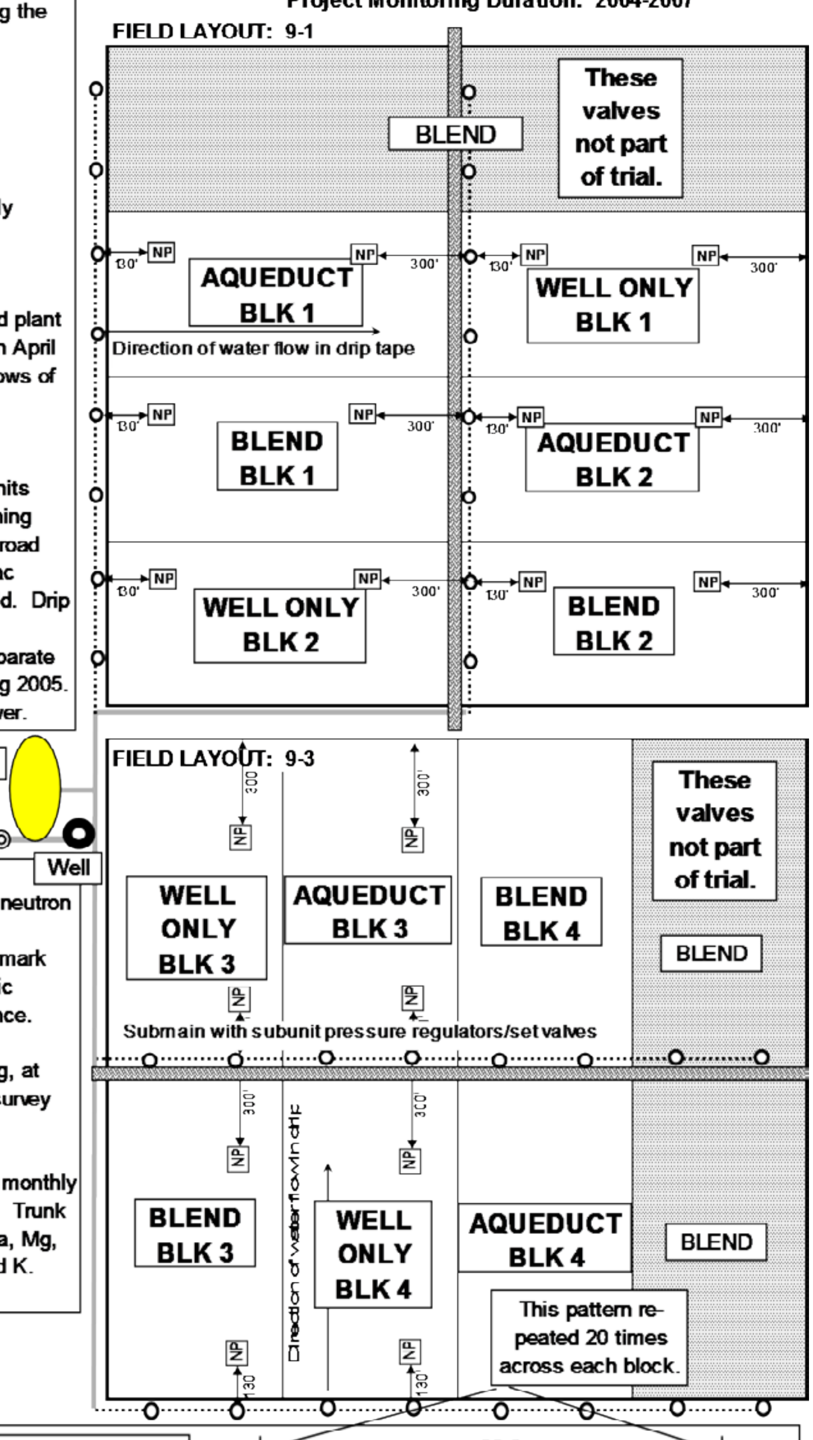
USDA Salinity Laboratory
Riverside CA

Greenhouse Trial Results

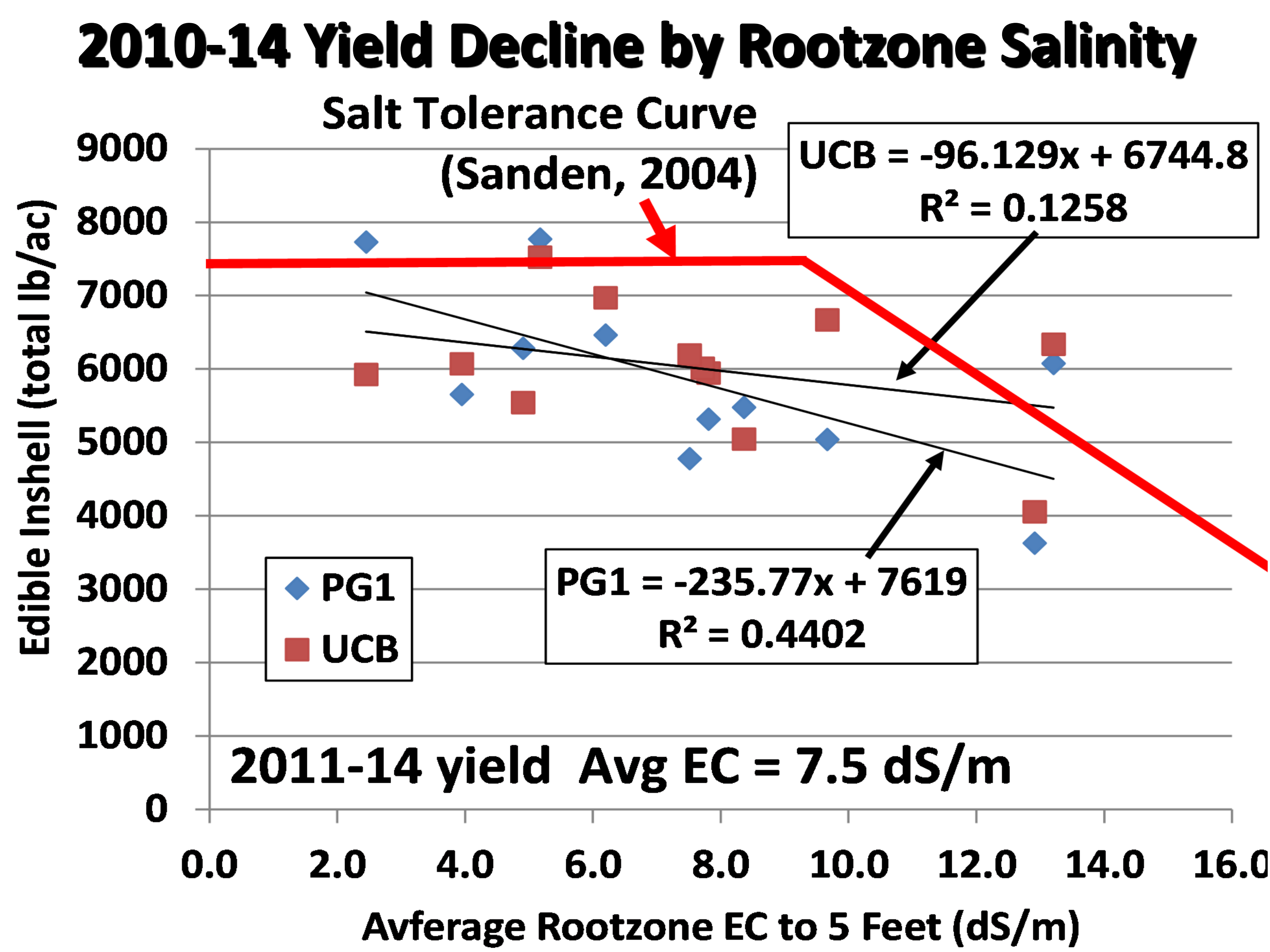
- Greenhouse Trial: Growth
  - Osmotic effects > specific ion damage
  - Differences among rootstocks in:
    - Sodium exclusion
    - Sodium and chloride transport and storage
  - Rootstock Ranking
    - 8 dS/m: PGI = UCBI = Atlantica
    - 12 dS/m: Atlantica = UCBI > PGI
    - 16 dS/m: Atlantica = UCBI >>> PGI

Second Salinity Field Trial 2004 - 2014

- Established in saline conditions
- Two Rootstocks
  - PGI and UCB I
- Three Salinity Levels
  - Aqueduct, 50:50, Well
- Growth and Yield


FIELD LAYOUT: 9-1
BLEND
These valves not part of trial.
AQUEDUCT BLK 1
WELL ONLY BLK 1
Direction of water flow in drip tape
BLEND BLK 1
AQUEDUCT BLK 2
WELL ONLY BLK 2
BLEND BLK 2
NP
130'
300'
FIELD LAYOUT: 9-3
Well
WELL ONLY BLK 3
AQUEDUCT BLK 3
BLEND BLK 4
These valves not part of trial.
BLEND
Submain with subunit pressure regulators/set valves
BLEND BLK 3
Direction of water flow in drip
WELL ONLY BLK 4
AQUEDUCT BLK 4
BLEND
This pattern re-peated 20 times across each block.

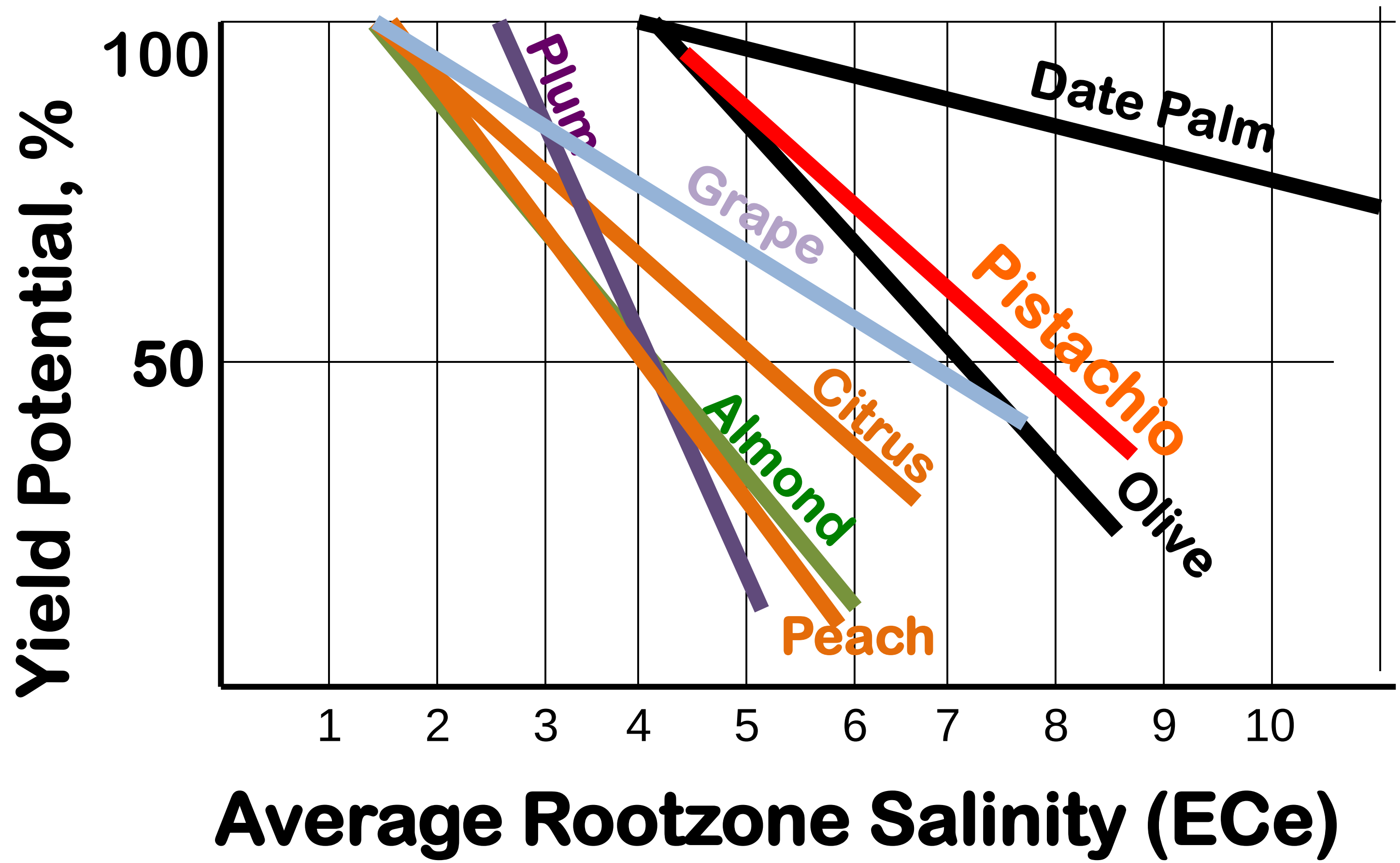

Belridge Salinity Trial
2, 155 acre fields
12, 19.5 acre test plots


2010-14 Yield Decline by Rootzone Salinity
Salt Tolerance Curve
(Sanden, 2004)
UCB = -96.129x + 6744.8
R² = 0.1258
PG1 = -235.77x + 7619
R² = 0.4402
PG1
UCB
2011-14 yield Avg EC = 7.5 dS/m
Edible Inshell (total lb/ac)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Avferage Rootzone EC to 5 Feet (dS/m)

Second Salinity Field Trial Results 2004 - 2014

- Treatment level -> final EC_e
  - Aqueduct: 0.5 -> 3.5
  - 50:50 Blend: 3.2 -> 16.7
  - Well: 5.2 -> 25.2
- Lowered EC_e to 6 dS/m
  - UCBI: 100 lb decline per /1 dS/m = 1.4%
  - PGI: 236 lb decline per 1 dS/m = 3.2%
- Rootstock tolerance UCBI > PGI
  - PGI better with aqueduct water

Tree Salt Tolerance



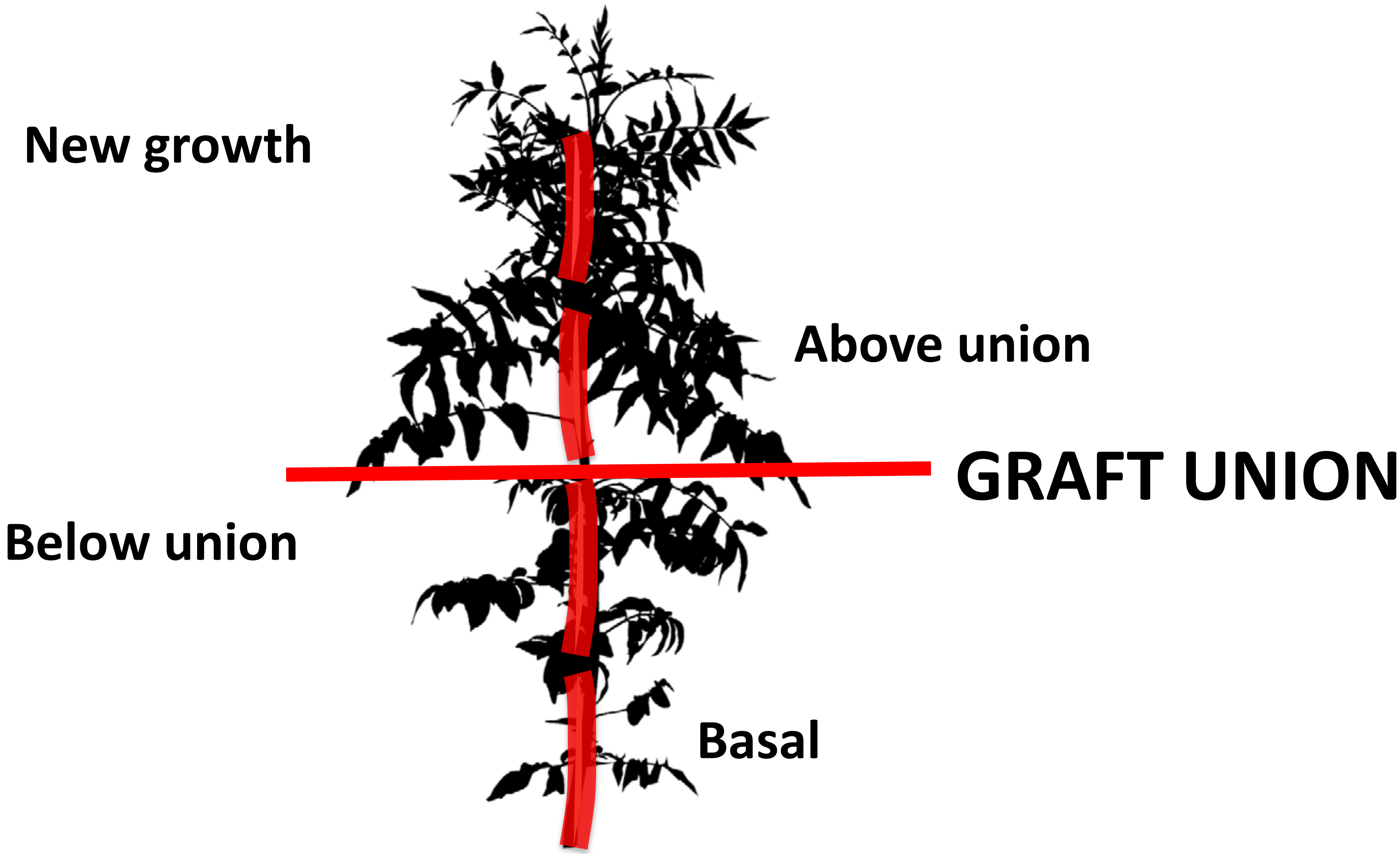
Maas and Grattan 1999
Ferguson et al., 2002

Mechanism of Salinity Tolerance?

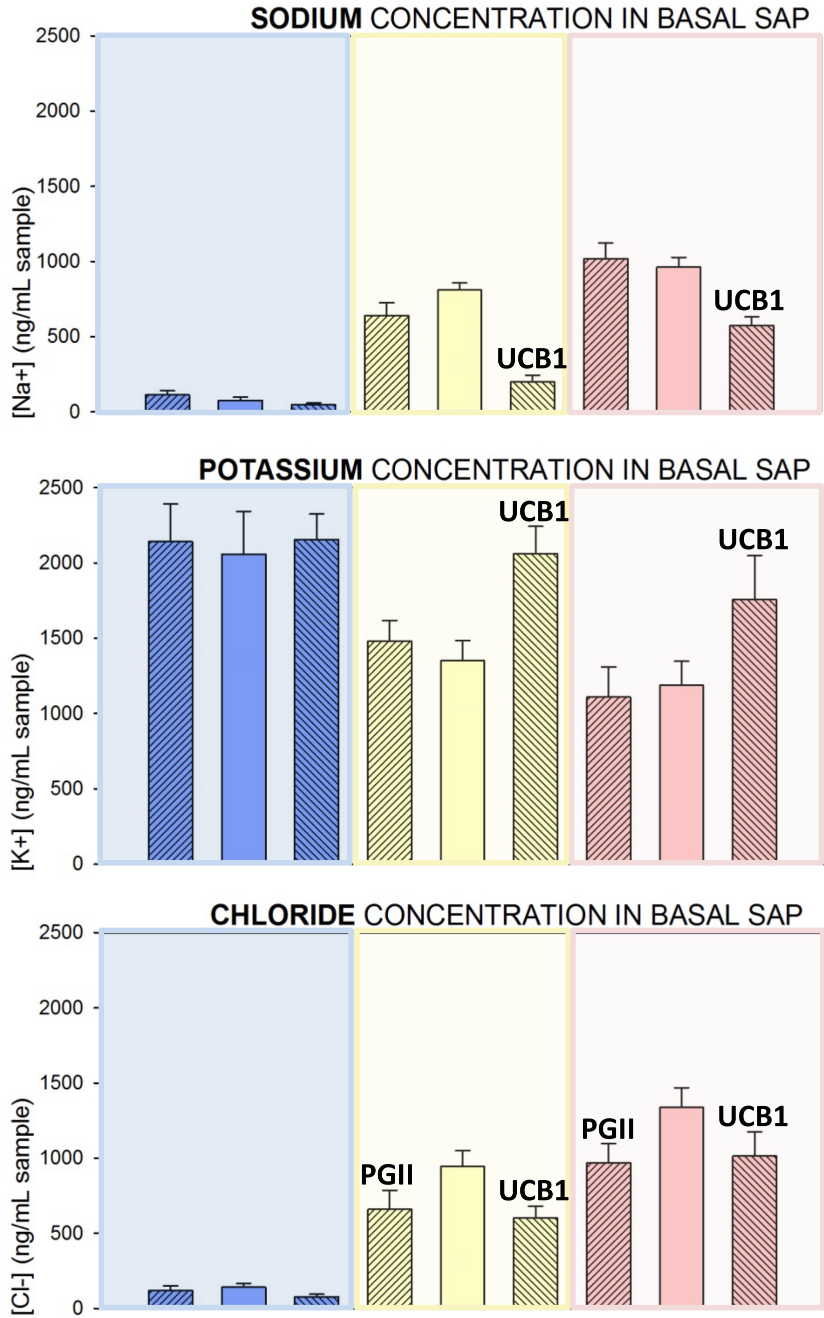
- How is it excluded, transported and stored in the plant?
- Where is it in plant cells?

Study I:

Sap sampling for sodium and chloride exclusion, transport and storage….



NA and CL Concentrations in Basal Sap by Roostock

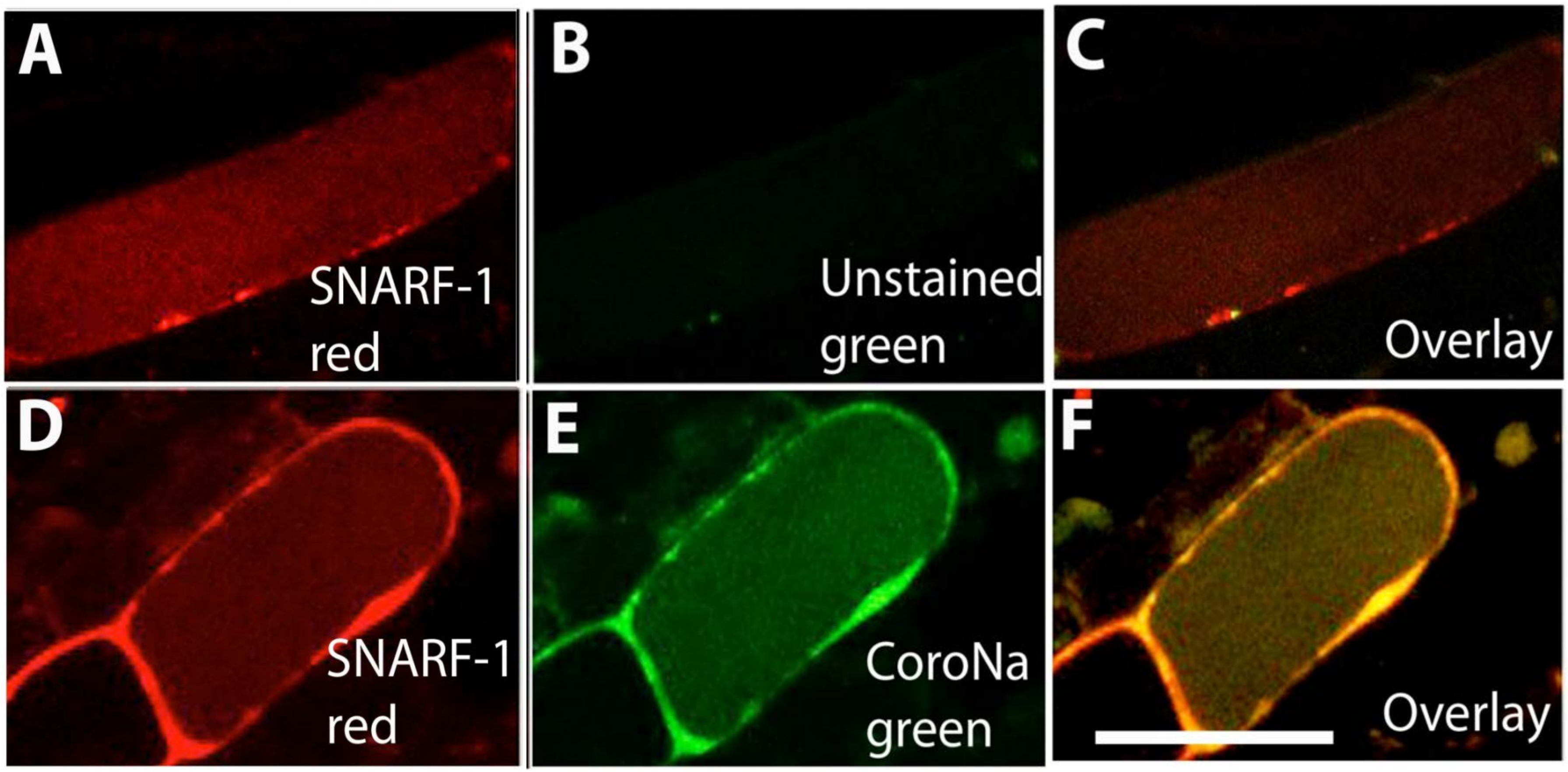


Sodium excluder: UCB1

UCBI Sodium exclusion: selectivity potassium.

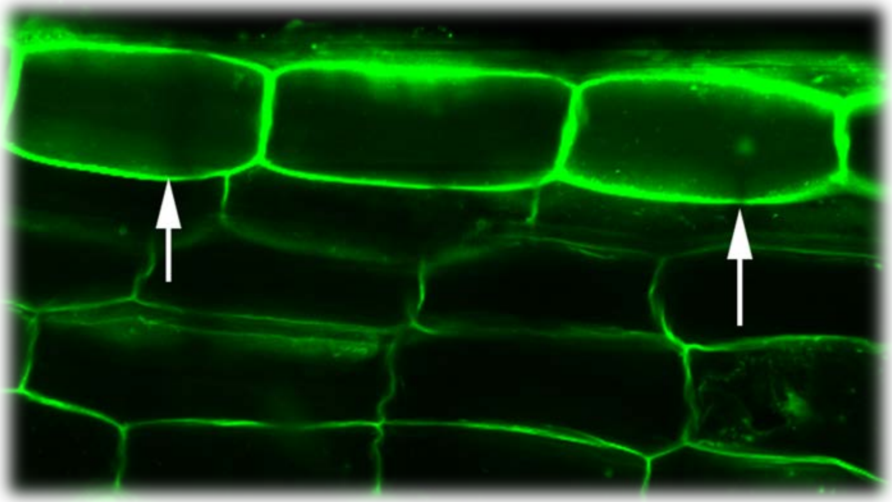
Chloride excluders: PGII UCB1

Sodium Localization in the Vacuole of Pistachio Cells

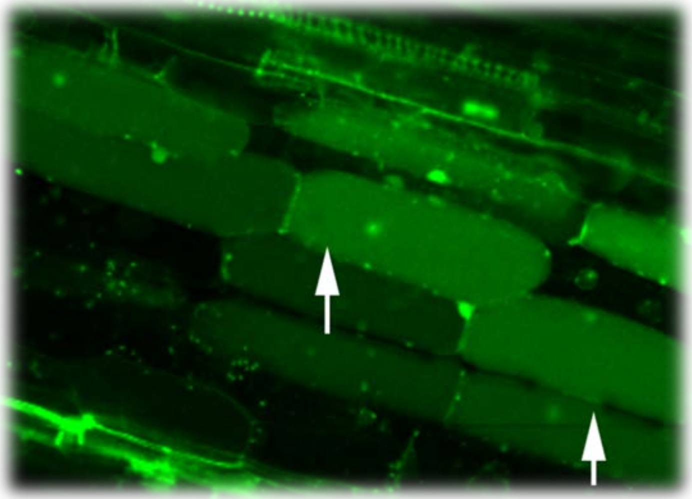


Potassium and Sodium Localization: UCBI Rootstock Cells

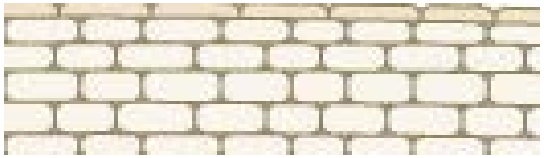
Potassium
Assante - K Green



Sodium
CoroNa Green

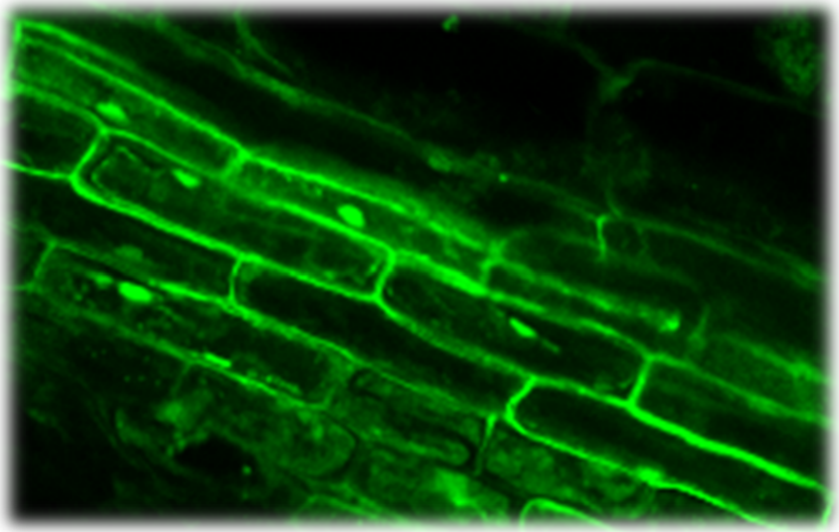


Distinct subcellular localization patterns of sodium and potassium in pistachio rootstock cells

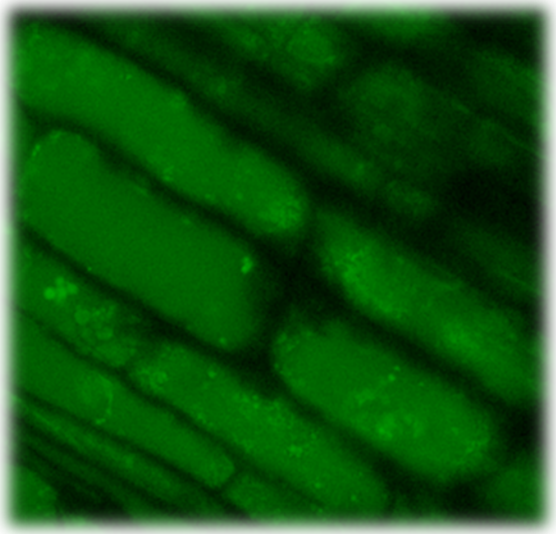


Potassium and Sodium Localization: Atlantica Rootstock Cells

Potassium
Assante -K Green



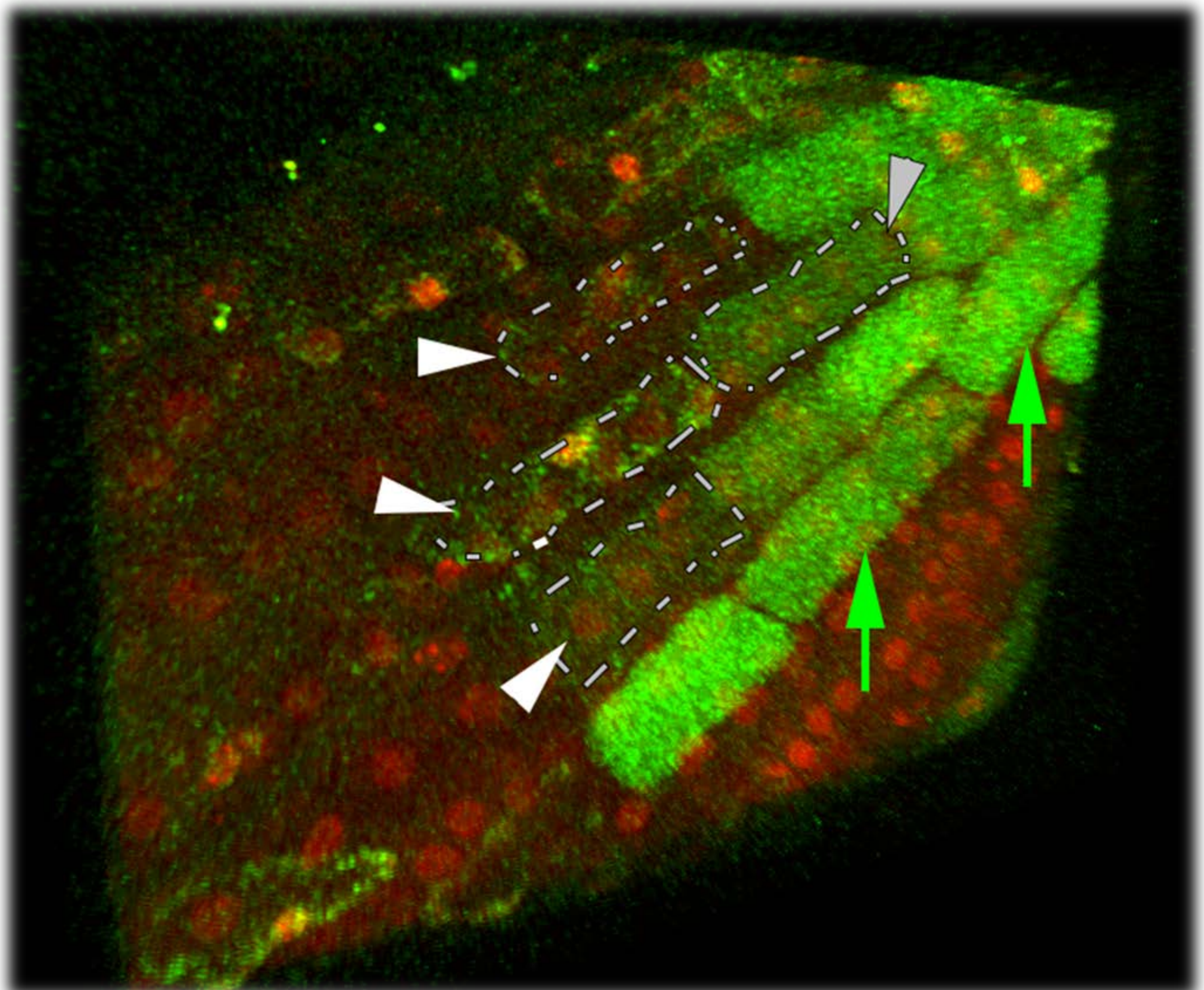
Sodium
CoroNa Green



Distinct subcellular localization patterns of sodium and potassium in pistachio rootstock cells

Chloride Localization Rootstock Cells

Root tip longitudinally section



Significance?

- how the mechanism for salinity tolerance works..
- Identified individual rootstocks
- genetically characterize rootstocks
- identify additional rootstocks
    - genomic projects now funded by CPRB (Letters)
  - tested in lab
  - orchard trial

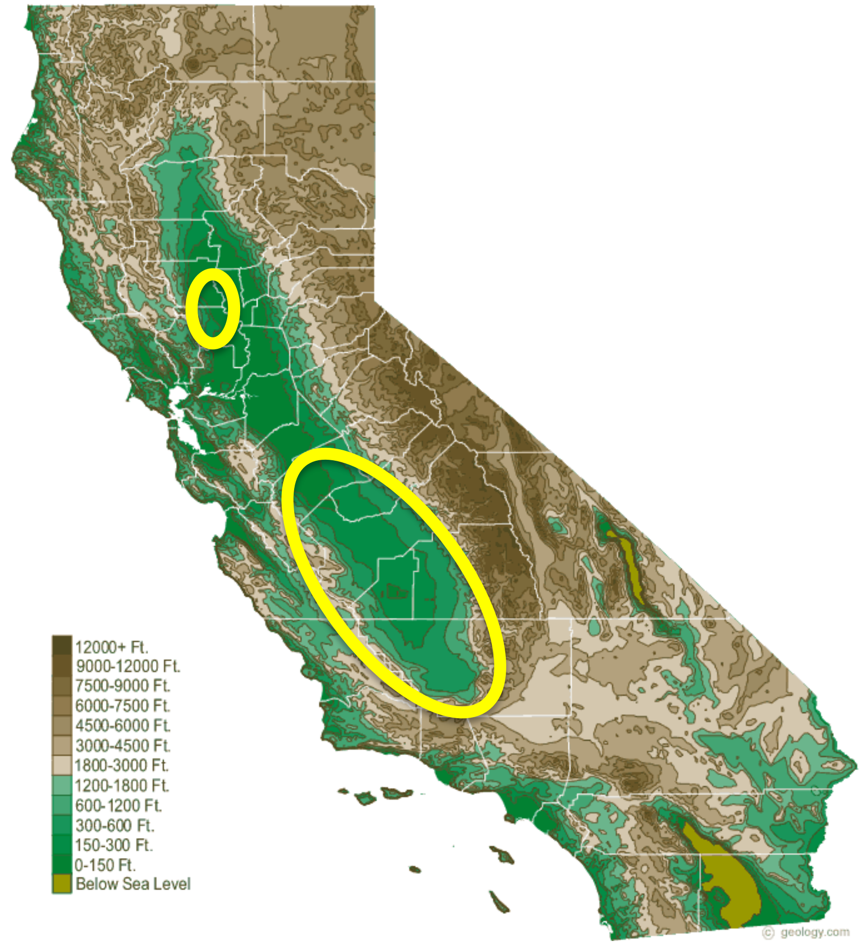
So, What do I do now…

“Salinity in soil and water is irrevocably associated with irrigated agriculture throughout the world.”

James E. Ayars, 2003

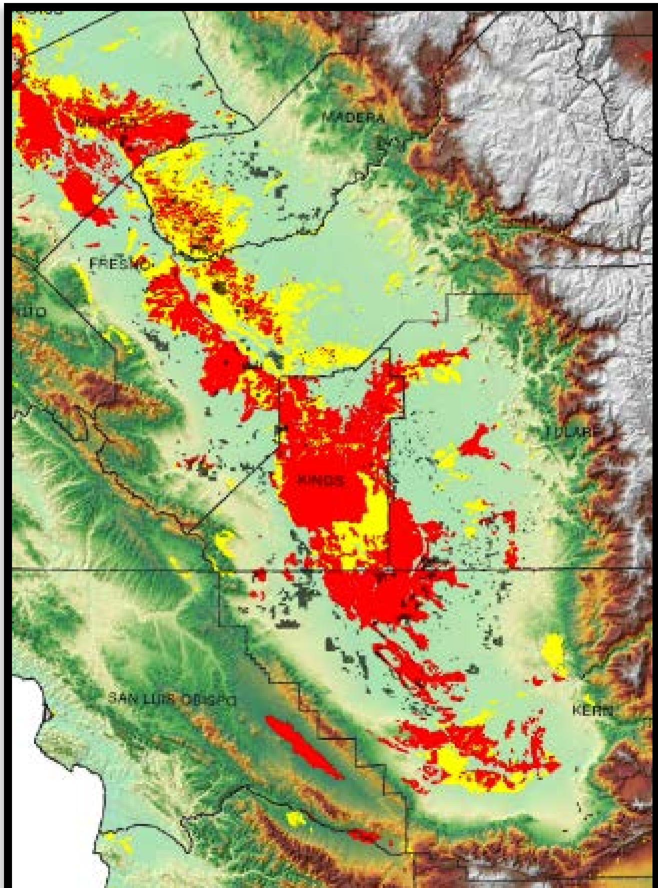
Orchard Location Limitations

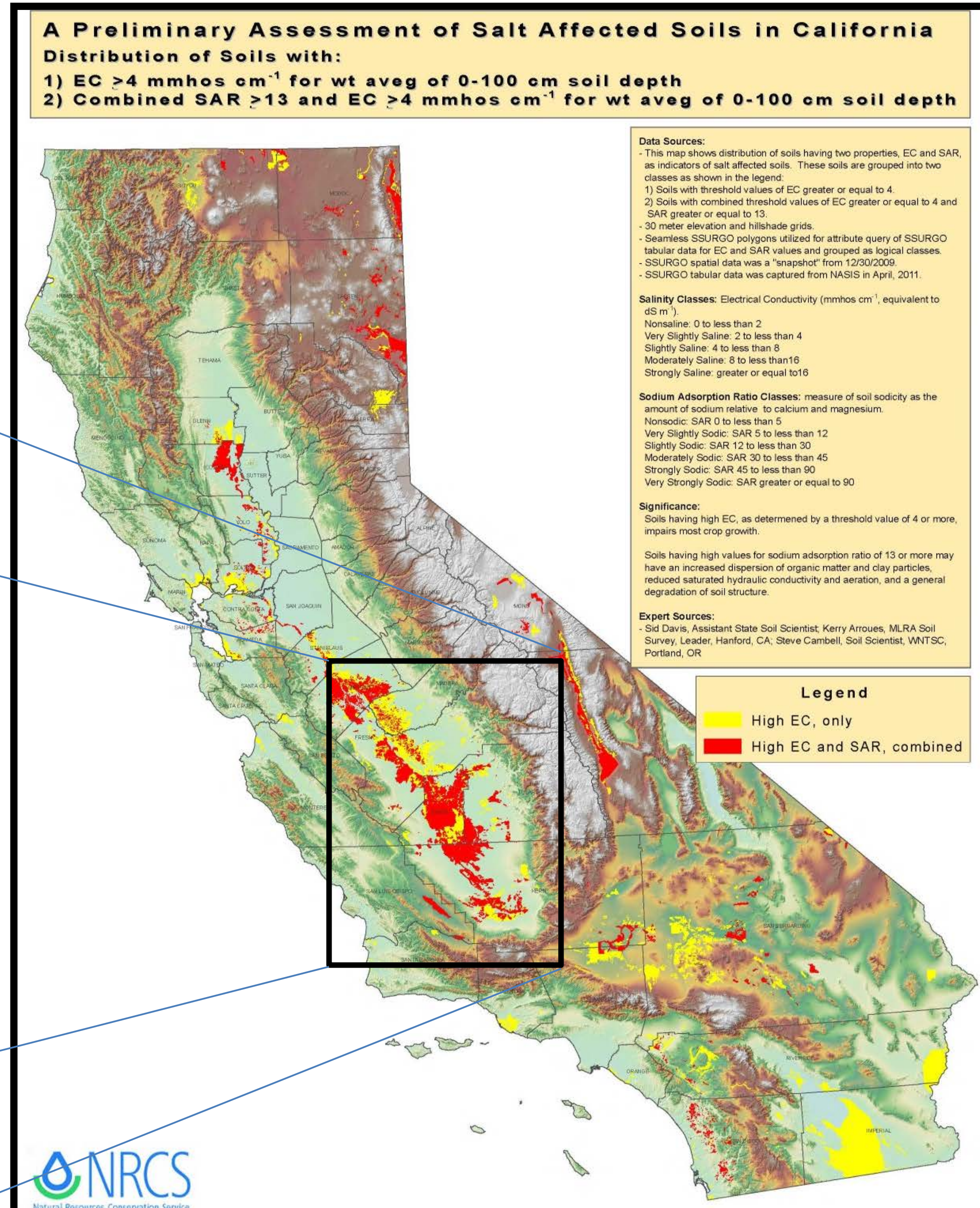
- **Limitations:**
  - **<2500' for frost**
  - **Climate(heat, chill, rain)**
  - **Water Availability**
  - **Water and Soil Quality**



Saline Sodic Areas

EC > 4 dS/m **SAR > 13**



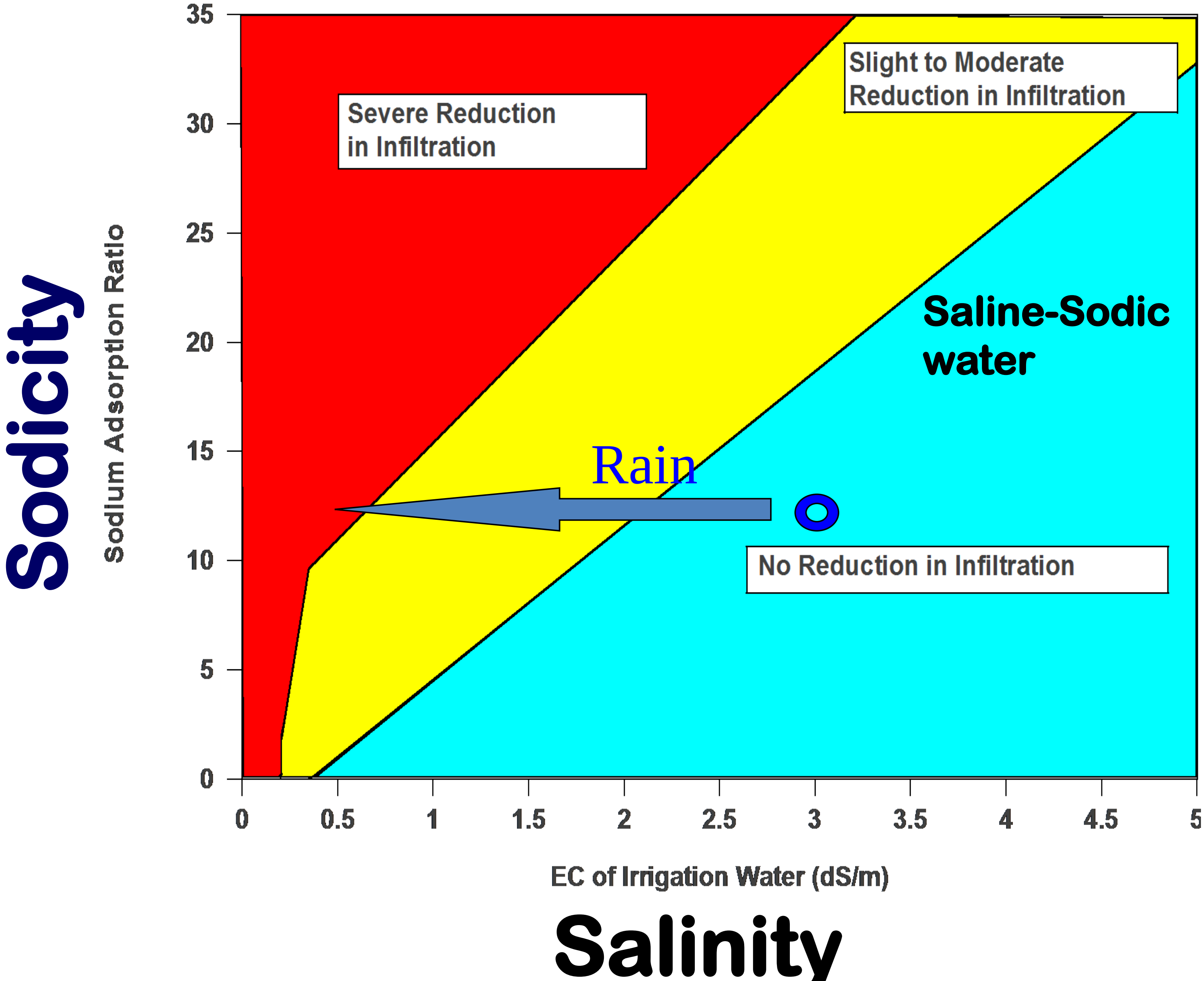


Salinity vs. Sodicity

- **Salinity is when the salt concentration is high enough to reduce crop yield: electrical conductivity = EC**

- **Sodicity is when water is dominated by sodium (Na^+):**
  - **affects soil structure**
    - **-> aeration -> water infiltration -> plant health**
  - **Sodium Adsorption Ratio: SAR**
  - **Exchangeable Sodium Percentage: ESP**

EC + SAR and Infiltration



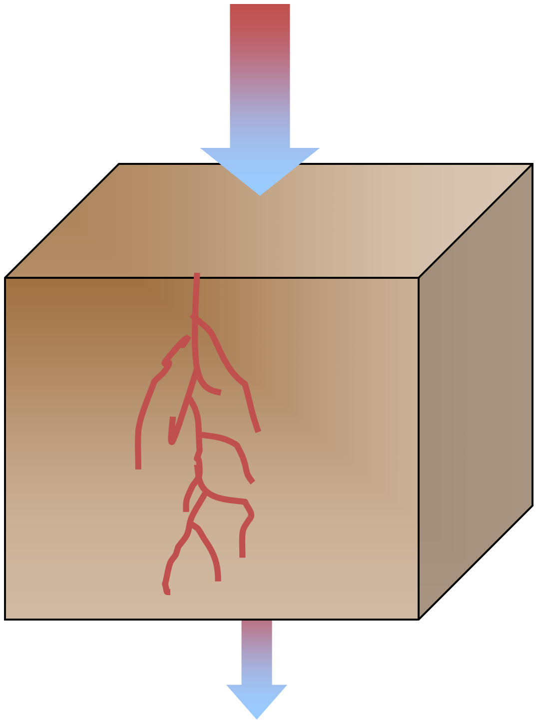
Sodicity First Salinity Second

- **Sodicity: gypsum**
  - $Na^{+}:Ca^{++} = 2$*
- **Leaching: winter**
  - evaporative demand is low

*Mortaz, Grattan, Brown and Ferguson 2016

Leaching Fraction (LF)

volume of water
draining
<u>Below rootzone</u>
volume of water
infiltrating ground



Leaching most effective in winter

Calculating Leaching Fractions

- If want soil EC_e = dS/m of irrigation water
  - 33% leaching fraction
- EC_e = 2 X (dS/m of Irrigation water)
  - 10% leaching fraction
- EC_e = 3 X (dS/m of Irrigation water)
  - 5% leaching fraction

Salinity Management Guidelines

- Preplant: soil and water analysis:
  - combination remain -> 6 dS/m
- Preplant: PGII and UCBI rootstocks
- Production: address sodicity then salinity
- Sodicity: Na^{+}:Ca^{++} ratio = 2 (gypsum)
- Production: leaf, soil, water (in order)
  - Bo “toxicity” not toxic until 1300 ppm August leaf sample
  - Na and Cl most toxic ions
    - difficult to distinguish and rarely seen
    - Cl first, then Na: both progressive damage
- Avoid dry soil profile with saline Ec_e
  - salinity + drought = severe damage
- Leach in winter or when EC_e = 6 dS/m

Thank You

California Pistachio Research Board
Wonderful Corporation
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Jessie Godfrey, Morad Mortaz, Zack Heath
Tunisia, Spain, China, Iran, Syria

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