Saline Irrigation Strategies for Pistachios: Current Research

- Blake Sanden, Giulia Marino, Mae Culumber, Louise Ferguson
- and
- Maricopa Ranch
- Semios
- Dellavalle Laboratories
- Ceres Imaging

Salinity and Salinity Tolerance: definitions

Salinity tolerance is the ability of plants to grow and complete their life cycle in a soil with high concentrations of soluble salts:

Salinity is dissolved salts in irrigation water or soil water:

Cations:

Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}

Anions:

SO_4^{2-}, Cl^{-}, HCO_3^{-}, CO_3^{2-}, NO_3^{-}

B:

H_3BO_3 (boric acid) and $H_2BO_3^{-}$ (borate))

- adds little to salinity
- most visible damage

Measured as Conductivity:

- an electrical current:

miilihos/cm – dS/m

.

Central Valley Soil Salinity:

***California Water Research Report*:**

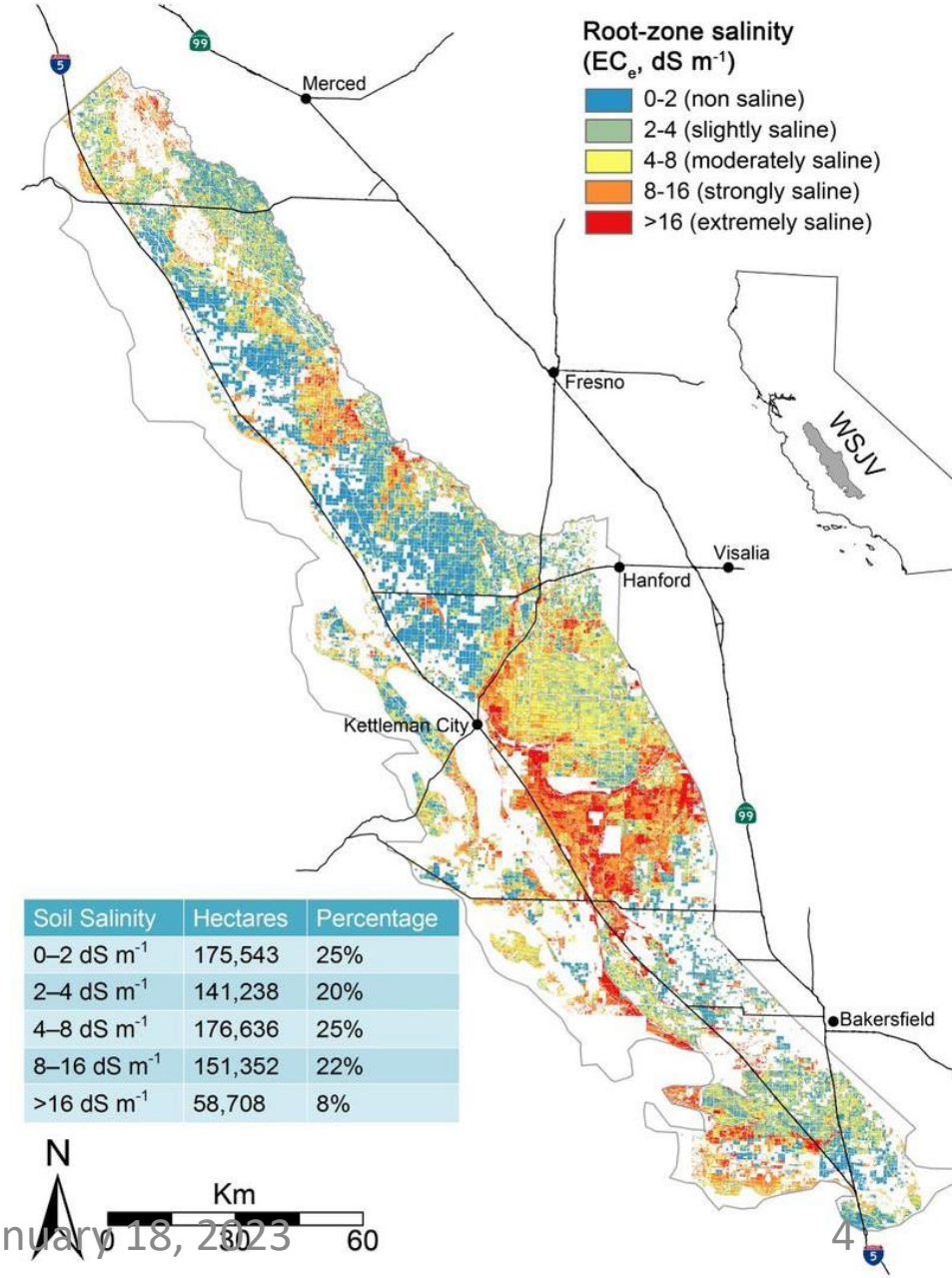
April 22nd 2019:

- **Merced: – 51%%**
- **Fresno: – 36%**
- **Tulare: - 89%**
- **Kings: - 66%**
- **Kern: - 55%**

"….soils range from 4-16 dS/m"

and

…counties 85% of bearing pistachio acres.



Soil Salinity	Hectares	Percentage
0–2 dS m^{-1}	175,543	25%
2–4 dS m^{-1}	141,238	20%
4–8 dS m^{-1}	176,636	25%
8–16 dS m^{-1}	151,352	22%
>16 dS m^{-1}	58,708	8%

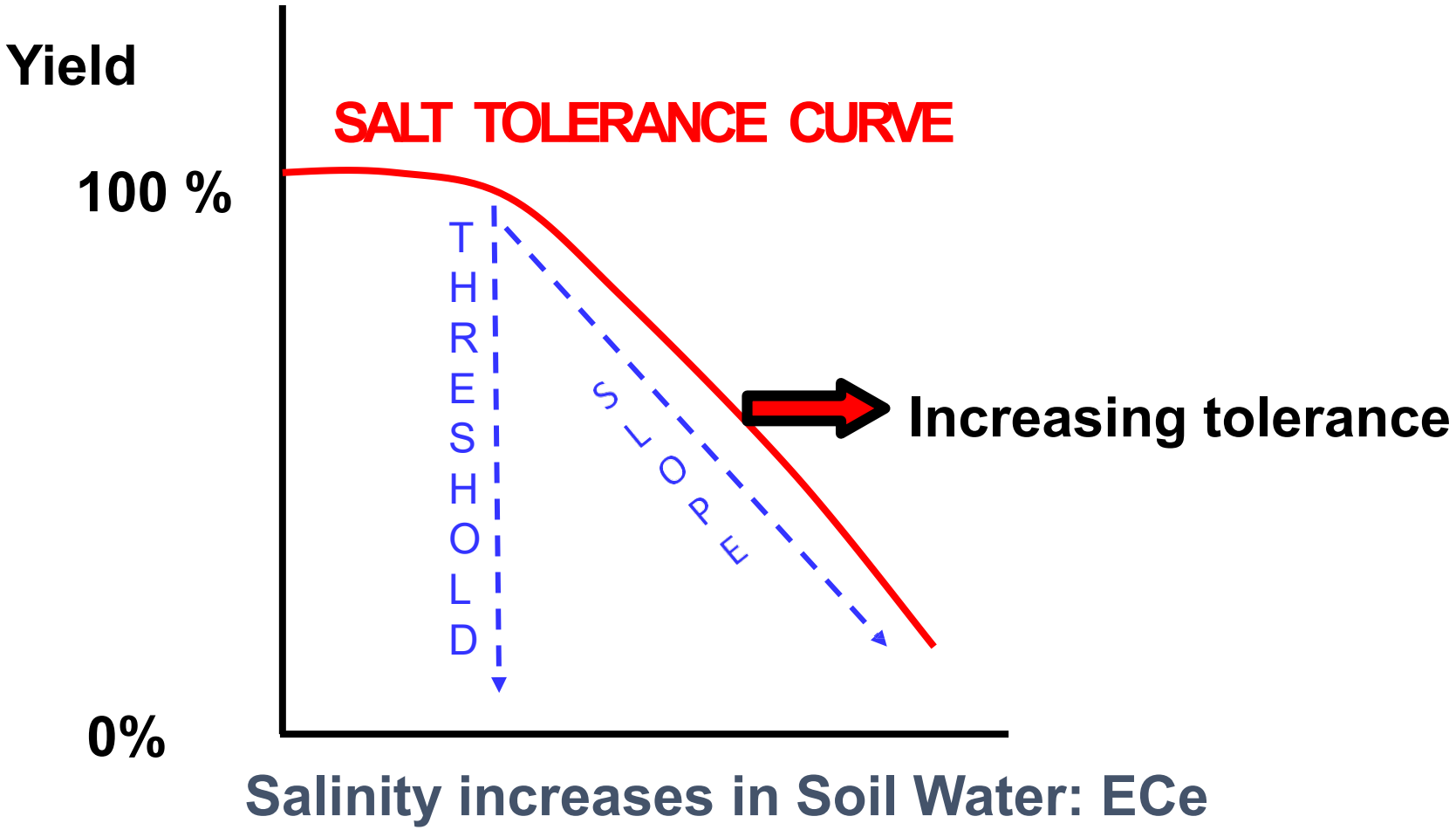
Pistachio salinity (in)tolerance appears as…

Osmotic Pressure

Pistachio salinity (in)tolerance appears as…

Specific ion damage: xylem mobile → newest growth → B

Pistachio salinity tolerance characterized…



Pistachio salt tolerance: how to study it ?

Container studies:

Field Trials:

Pistachio salt tolerance: how to study it ?

Container studies:

Advantages:

- control
- no saturation hypoxia
- Isolate specific ions
- detailed physiology
- detailed anatomy

Disadvantages:

- young, nonbearing
- unbudded
- short term

Primary Functions:

- preliminary studies
- relative ranking of rootstocks, scions and combinations based on growth and visible damage
- effect of the bud union
- direct how to do a field study

Field Trials:

Advantages:

- true tree behavior integrating
  - osmotic pressure
  - specific ion damage
  - yield
  - alternate bearing

Disadvantages:

- results are only as good as experimental design, orchard, treatment methods:
  - When initiated
  - Soil composition
  - Soil uniformity
  - Irrigation method
  - Irrigation timing
  - Monitoring methods

Primary Function:

- develop management practices

Pistachio salinity studies: results

<u>Container studies</u>:
Ferguson and Sanden: 2002

Godfrey, Ferguson, Zwieniecki: 2019

Zhang, Ferguson, Drakakaki: 2020

Godfrey, Ferguson and Zwieniecki: 2021

<u>Field Trials:</u>
Ferguson and Sanden: 2002

Sanden, Kallsen, Grattan and Ferguson: 2014

2002 Container Trial: Ferguson and Sanden

Determined rootstock ranking

- **Atlantica > UCBI > PGI**

- **Osmotic effects > specific ion**

- **Differences in Na exclusion**

- **Difference in Na and Clt transport and storage**

- **Established only B produced leaf symptoms, “Boron Toxicity”**

J. A MER. S OC. HORT . SCI. 127(2):194–199. 2002.
Pistachio Rootstocks Influence Scion Growth and Ion Relations under Salinity and Boron Stress


Na CL NA CL Na
B B

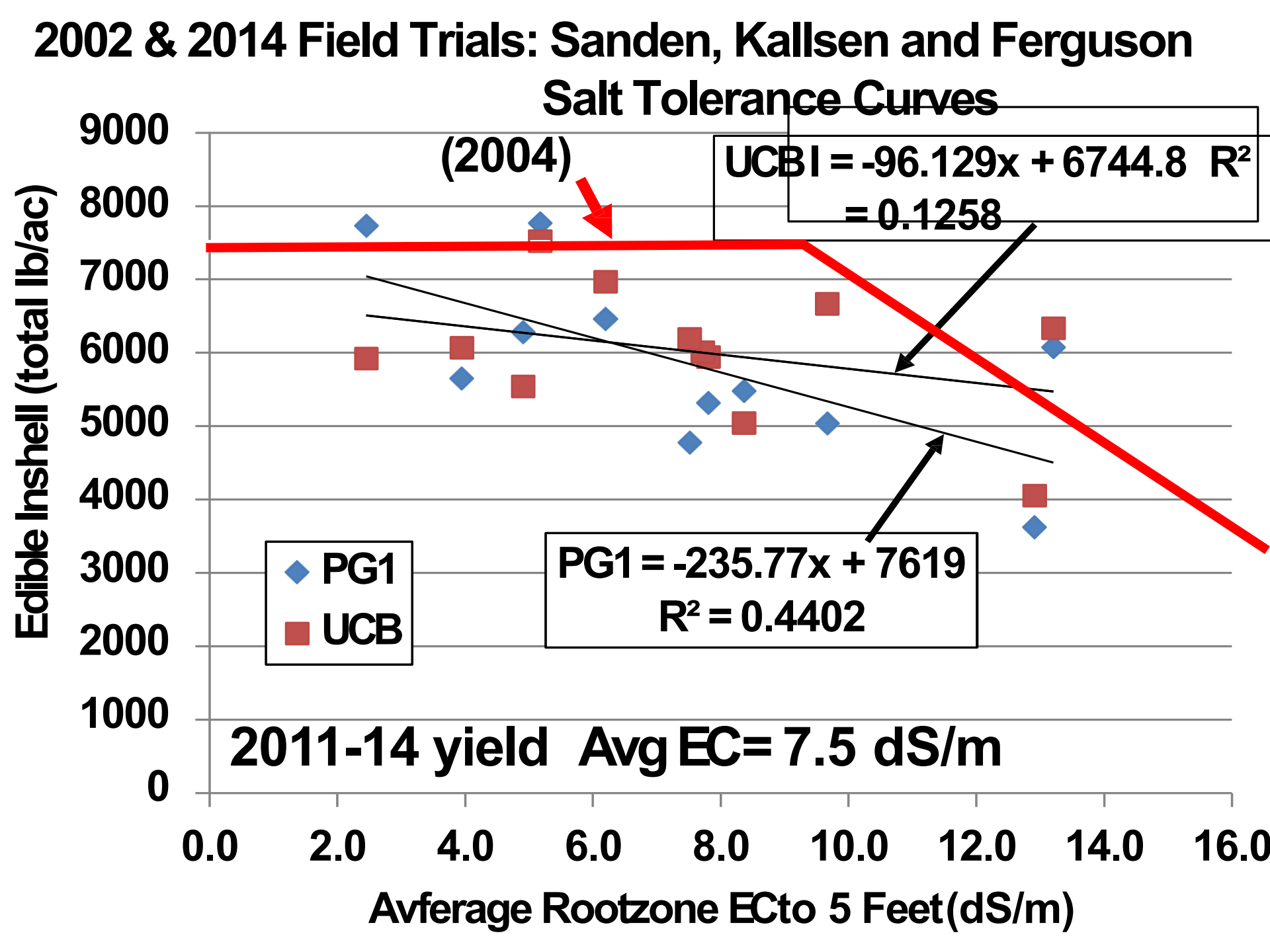
2002 Field Trial: Ferguson and Sanden

Osmotic pressure first effect on growth and yield versus specific ion damage

https://calpistachioresearch.org/wp-content/uploads/2018/03/02283.pdf

2014 Field Trial: Sanden, Kallsen and Ferguson

Osmotic pressure first effect on growth and yield versus specific ion damage

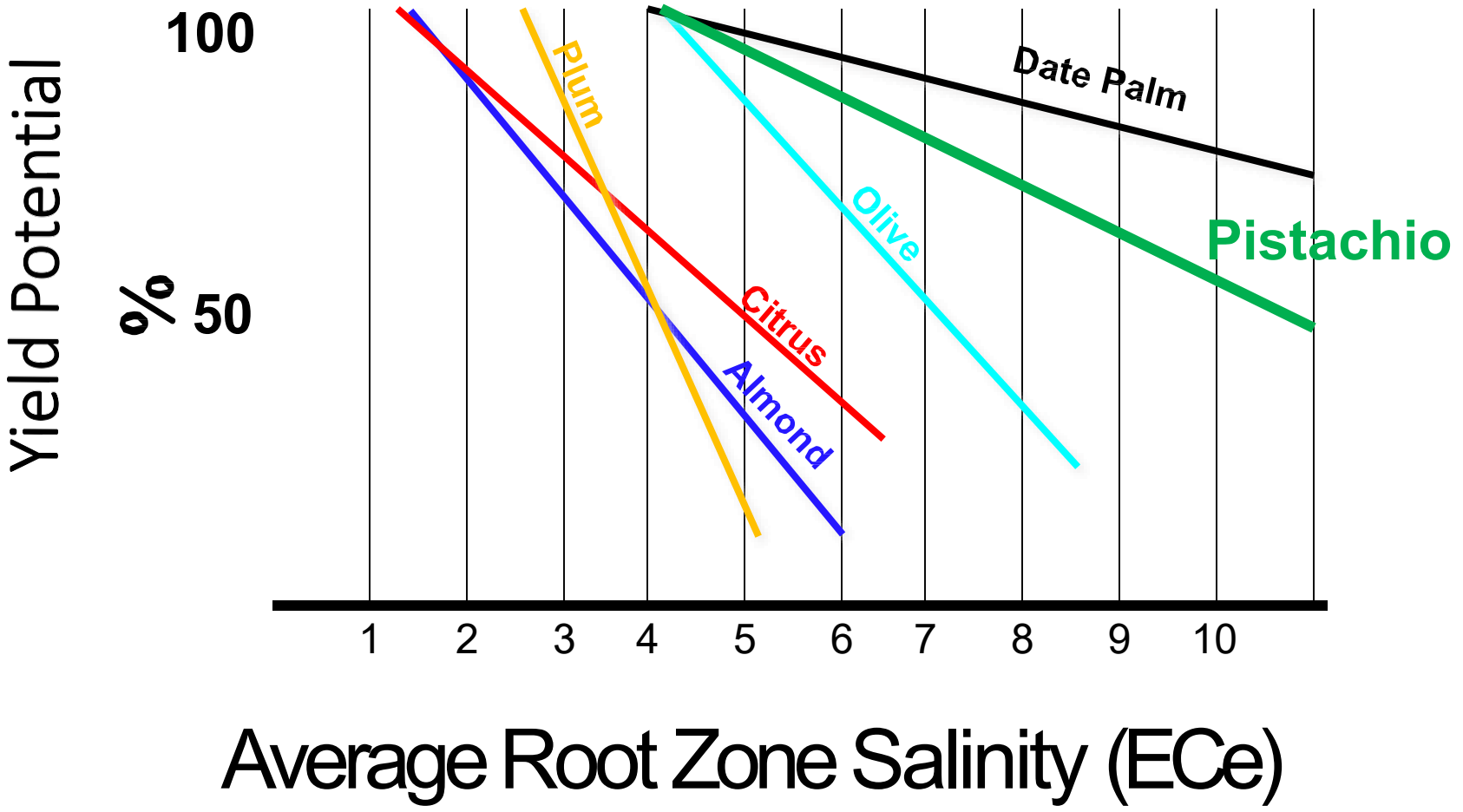

2002 & 2014 Field Trials: Sanden, Kallsen and Ferguson
Salt Tolerance Curves
(2004)
UCBI = -96.129x + 6744.8 R² = 0.1258
PG1 = -235.77x + 7619
R² = 0.4402
PG1
UCB
2011-14 yield Avg EC= 7.5 dS/m
Edible Inshell (total lb/ac)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Avferage Rootzone ECto 5 Feet(dS/m)

2002 & 2014 Field Trials: Sanden, Kallsen and Ferguson

- Orchards established ~ 5 years before application of salinity less affected
- Rootstock tolerance UCBI > PGI
- Lowered critical 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%

2002 and 2014 Field Trials: Sanden, Kallsen and Ferguson

Established Slope and Intercept Relative to Other Tree Crops



Container Trials: Godfrey, Ferguson, Zwieniecki

2019 study:

Na and Cl excluded from leaves:

Two mechanisms for NA
- **Na excluded at root**
- **Na retrieved from xylem**
  - **stored in xylem**

- **Cl recirculated in phloem**

Container Trials: Godfrey, Ferguson, Zwieniecki

2021 study:

Different CHO consequences for old and young plant parts:

- Xylem retrieval protects CHO of older plant parts reserves by sequestering Na; not used for osmoticum

- young bark and fine roots sacrificed CHO to form osmoticum: supports establishing under good conditions

Container Trials: Zhang, Ferguson, Drakakaki

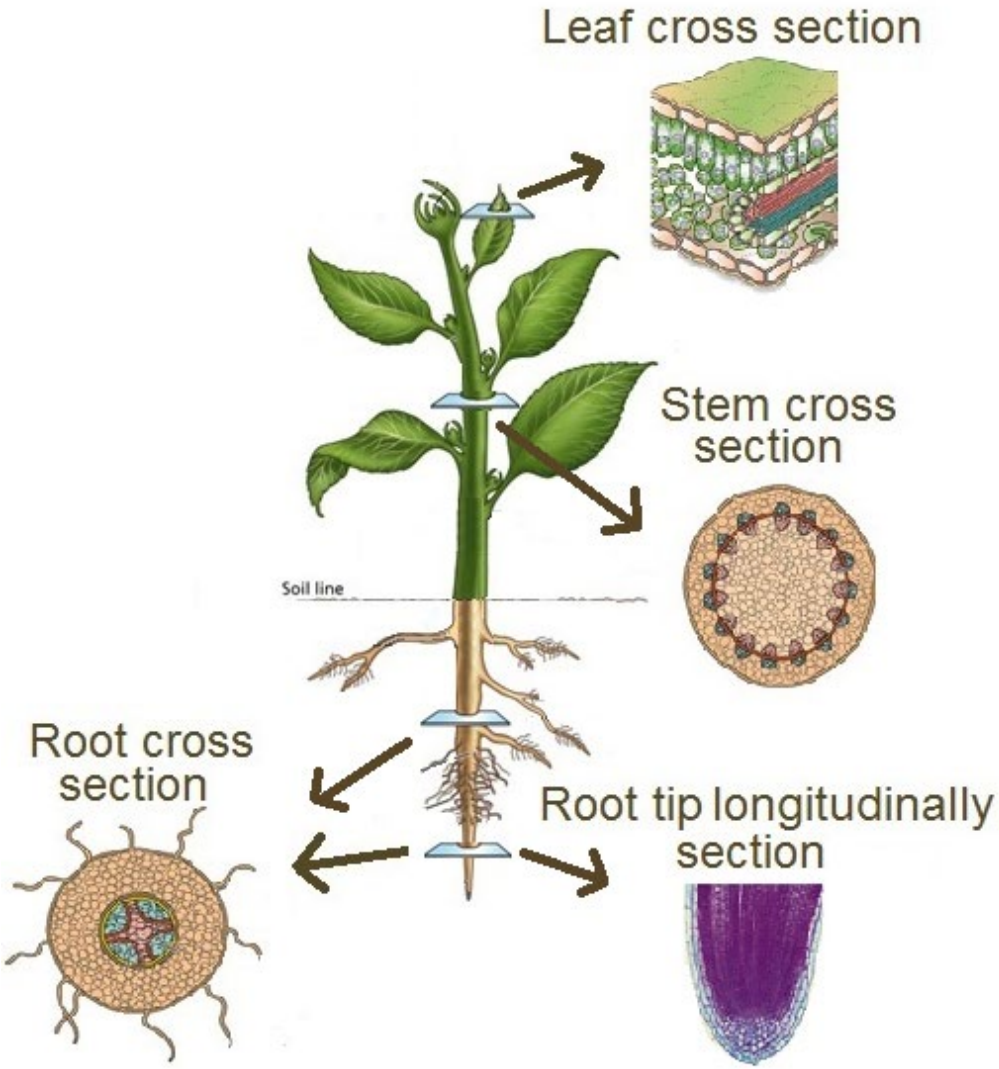
2021 study:

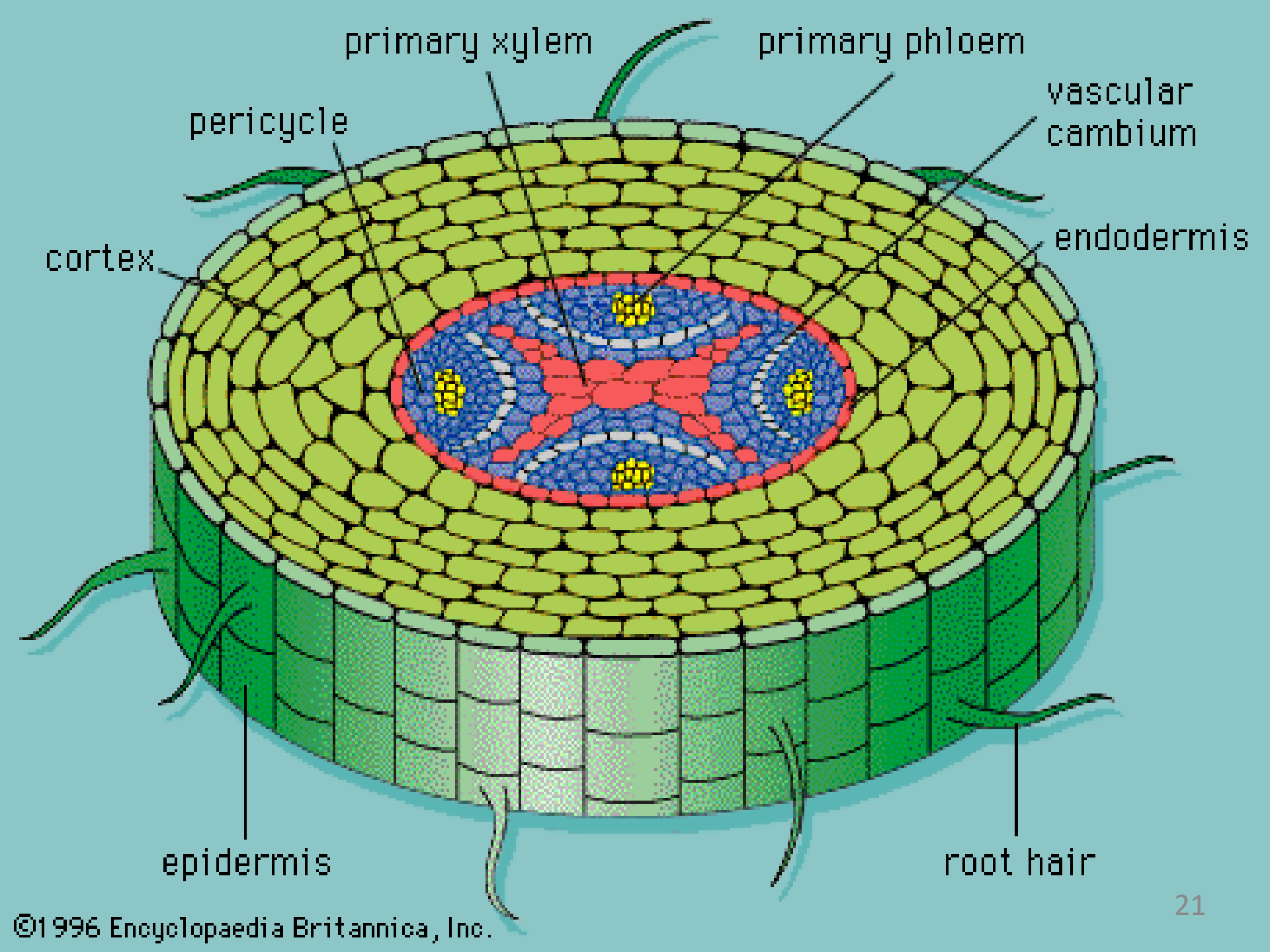
Corroborates Ferguson and Godfrey's results:

- UCBI versus PG excluded Na by:

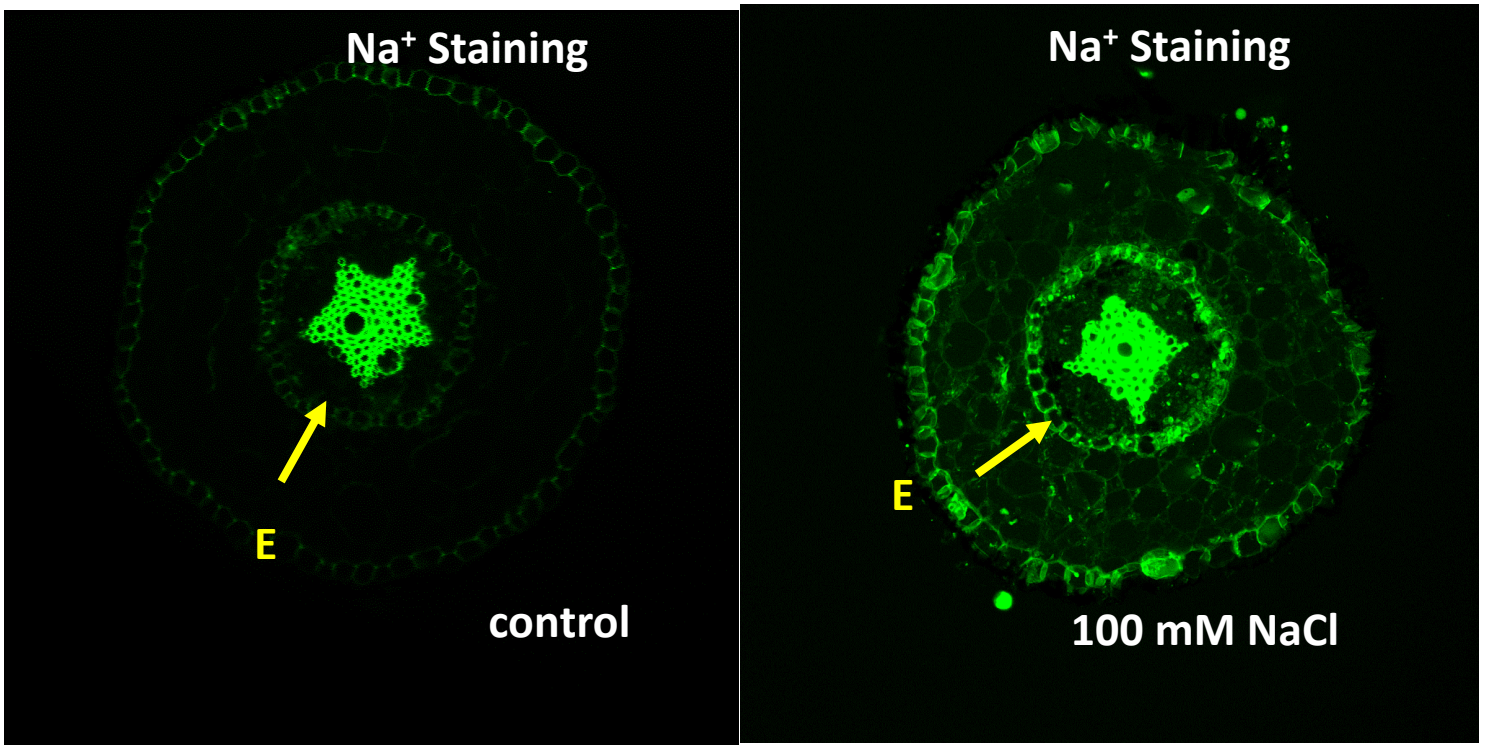
- suberization at root cortex

- sequestering Na in root vacuole



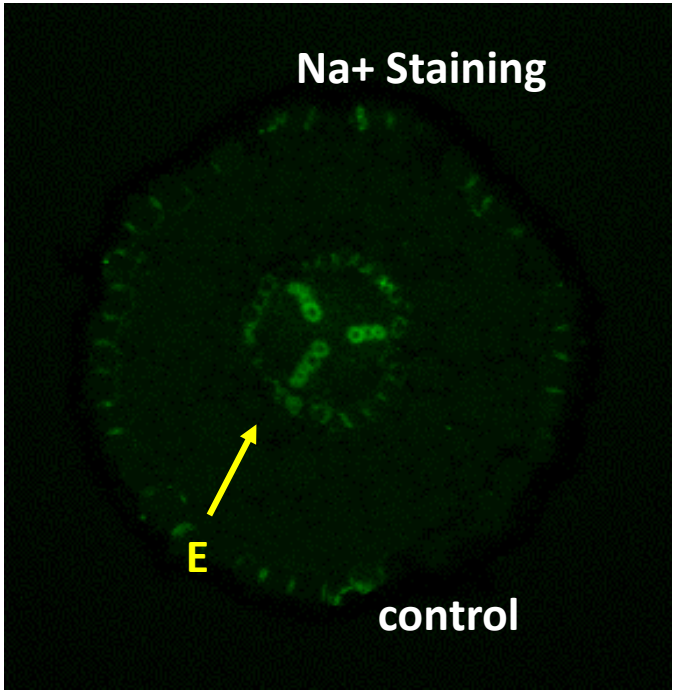

primary xylem
primary phloem
vascular cambium
pericycle
endodermis
cortex
epidermis
root hair
©1996 Encyclopaedia Britannica, Inc.

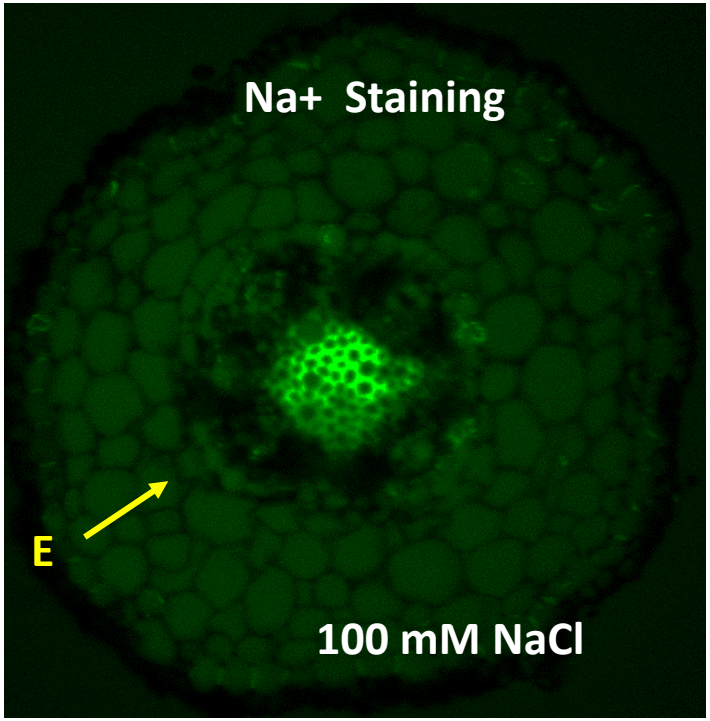
Sodium Accumulation in UCB-1 Roots: NaCl Treated



Enhanced staining of sodium in the endodermis and epidermis layer surrounding the plant vascular systems supports exclusion via the endodermis and epidermis layers

Sodium does not accumulate in epidermis and endodermis *of P. integerrima roots....*





No significant staining of sodium in endodermis and epidermis of *P. integerrima*...sodium is transported to leaves....

Summary: we now know…

- Salinity tolerance limits of our rootstocks and cultivar
- How salinity damage is produced and location of ions:
  - Boron toxicity, IKD
- Traditional and molecular breeding generating new rootstocks and cultivars: conservatively 10 years away

Summary: option is salinity management

Salinity management in soils and water:

- Irrigation system design
- Irrigation timing and volume
- Dormant leaching requirement
- In-season leaching fraction as a % of ETo
- Amendments
- Monitoring

Project Objective: salinity management

Investigate best method to monitor salt movement (out)

- Irrigation system design
  - Single vs double line
- Irrigation timing and volume
  - Dormant leaching requirement
    - In row vs whole field
  - In-season leaching fraction as a % of ETo
- Monitoring in real time: new technology
  - Tree growth, stress, nutrition and yield
  - Soil moisture and salinity in real time

Objective: experimental parmeters

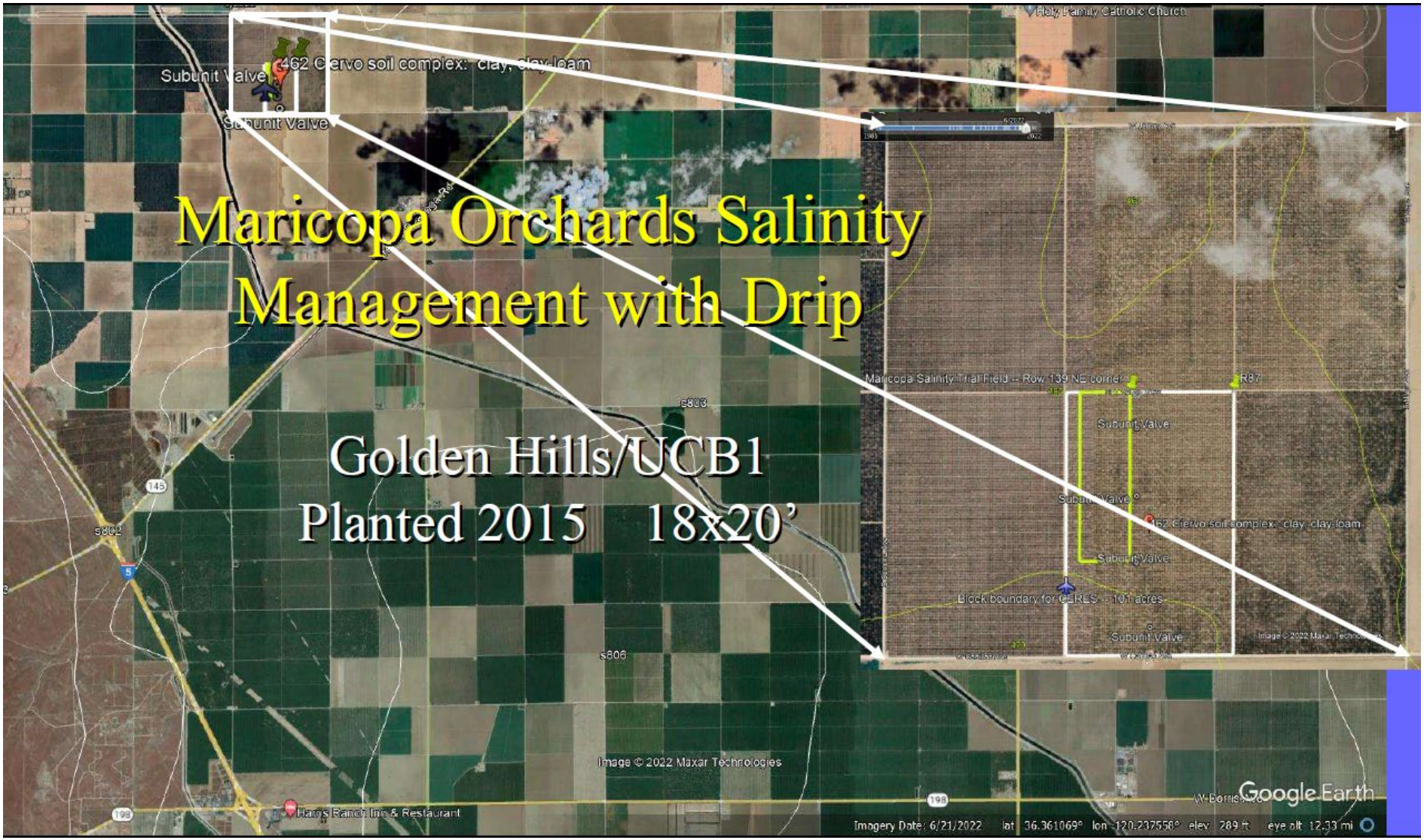
Most efficient management of salinity with drip irrigation:

- single- and double-line drip system:

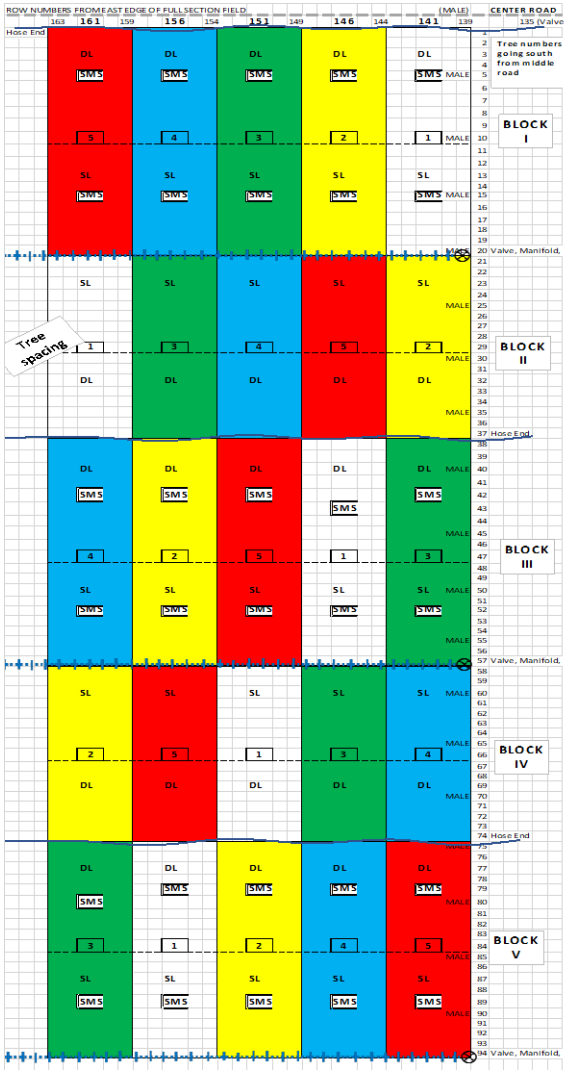
- +/- in-season 15% leaching

- +/- dormant pulsed leaching

Experimental Location: Maricopa Ranch



Experimental Design: Maricopa Ranch 5/2022



Maricopa drip trial design -- 50 plots

TREATMENTS USING SPLIT-PLOT DESIGN (single-hose vs double-hose split)

1. CONTROL: in-season scheduling to meet tree ET only. Max 2-3" post-harvest irrigation. 5.54 emitters/tree (39" spacing) @ 0.5 gph = 5.54 gph/tree = 0.59 inch/day

WHITE

2. (1) + PULSED WINTER REFILL/LEACHING: refill rootzone to 4-5 feet by pulsing 2 days on-2 days off, etc, maybe 6-10". Calculate ECe reclamation requirement as a comparison using fall soil samples. Using the full "refill" idea is easier for growers and should achieve sufficient reclamation in the top 2-3 feet.

YELLOW

3. (1) + LF: added 15% leaching fraction (LF) with every irrigation applied by snaking hose to achieve 6.37 gph/tree = 0.68 inch/day

GREEN

4. (3) + PULSED WINTER REFILL/LEACHING

BLUE

5. (1) FOR 3-4 YEARS FOLLOWED BY MAJOR WINTER PULSED LEACHING: 12-18 inches

RED

SPLITPLOT: SINGLE-LINE DRIP, DOUBLE LINE DRIP

Experimental monitoring in real time:

Ceres Imaging:

- NDVI
- WSC
- MCASR12
- Canopy Diameter
- TR
- CIR

Yield :

- Weight
- Edible yield

Field:

- Trunk diameter
- EM38
- SWP
- Photosynthesis
- Stomatal conductance

Dellavalle Laboratories

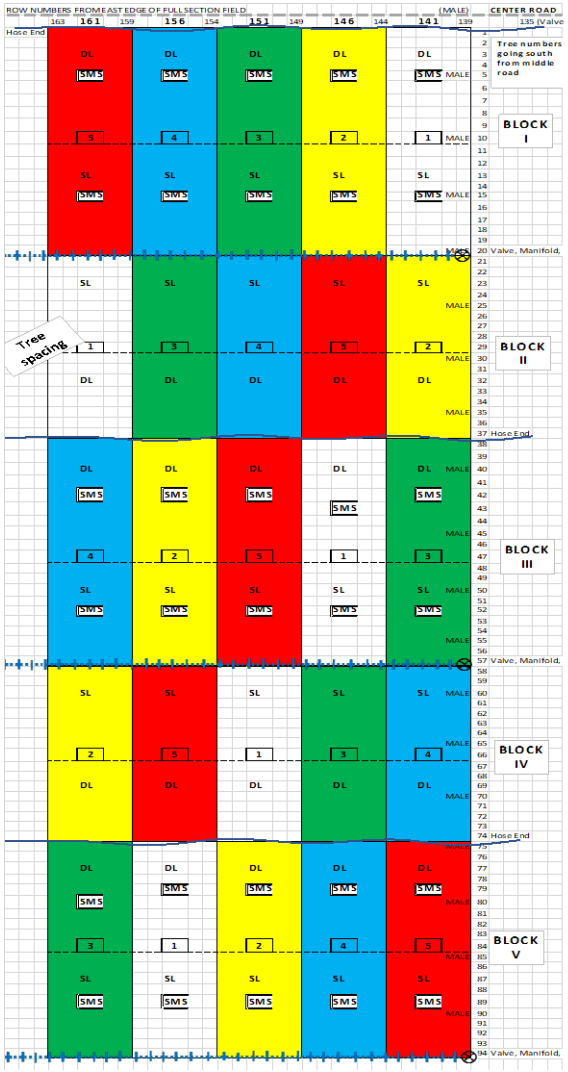
- Soil and leaf nutrients
- Soil pH and salinity ECe

Semios:

- Volumetric water content
- Available water content
- Volumetric ion content
- Daily shrinkage/total growth
- Drip line pressure
- Weather station


SEMIOS MONITORING SYSTEM
Center
0” (hose)
18”
36”

Results for 2022 season:



Maricopa drip trial design -- 50 plots

TREATMENTS USING SPLIT-PLOT DESIGN (single-hose vs double-hose split)

1. CONTROL: in-season scheduling to meet tree ET only. Max 2-3" post-harvest irrigation. 5.54 emitters/tree (39" spacing) @ 0.5 gph = 5.54 gph/tree = 0.59 inch/day

WHITE

2. (1) + PULSED WINTER REFILL/LEACHING: refill rootzone to 4-5 feet by pulsing 2 days on-2 days off, etc, maybe 6-10". Calculate ECe reclamation requirement as a comparison using fall soil samples. Using the full "refill" idea is easier for growers and should achieve sufficient reclamation in the top 2-3 feet.

YELLOW

3. (1) + LF: added 15% leaching fraction (LF) with every irrigation applied by snaking hose to achieve 6.37 gph/tree = 0.68 inch/day

GREEN

4. (3) + PULSED WINTER REFILL/LEACHING

BLUE

5. (1) FOR 3-4 YEARS FOLLOWED BY MAJOR WINTER PULSED LEACHING: 12-18 inches

RED

SPLITPLOT: SINGLE-LINE DRIP, DOUBLE LINE DRIP

Results thus far:

Soil profile established:

Semios system installed and verified:

<u>Treatment Differences:</u>

Double and single line +/- in season leaching vs control:

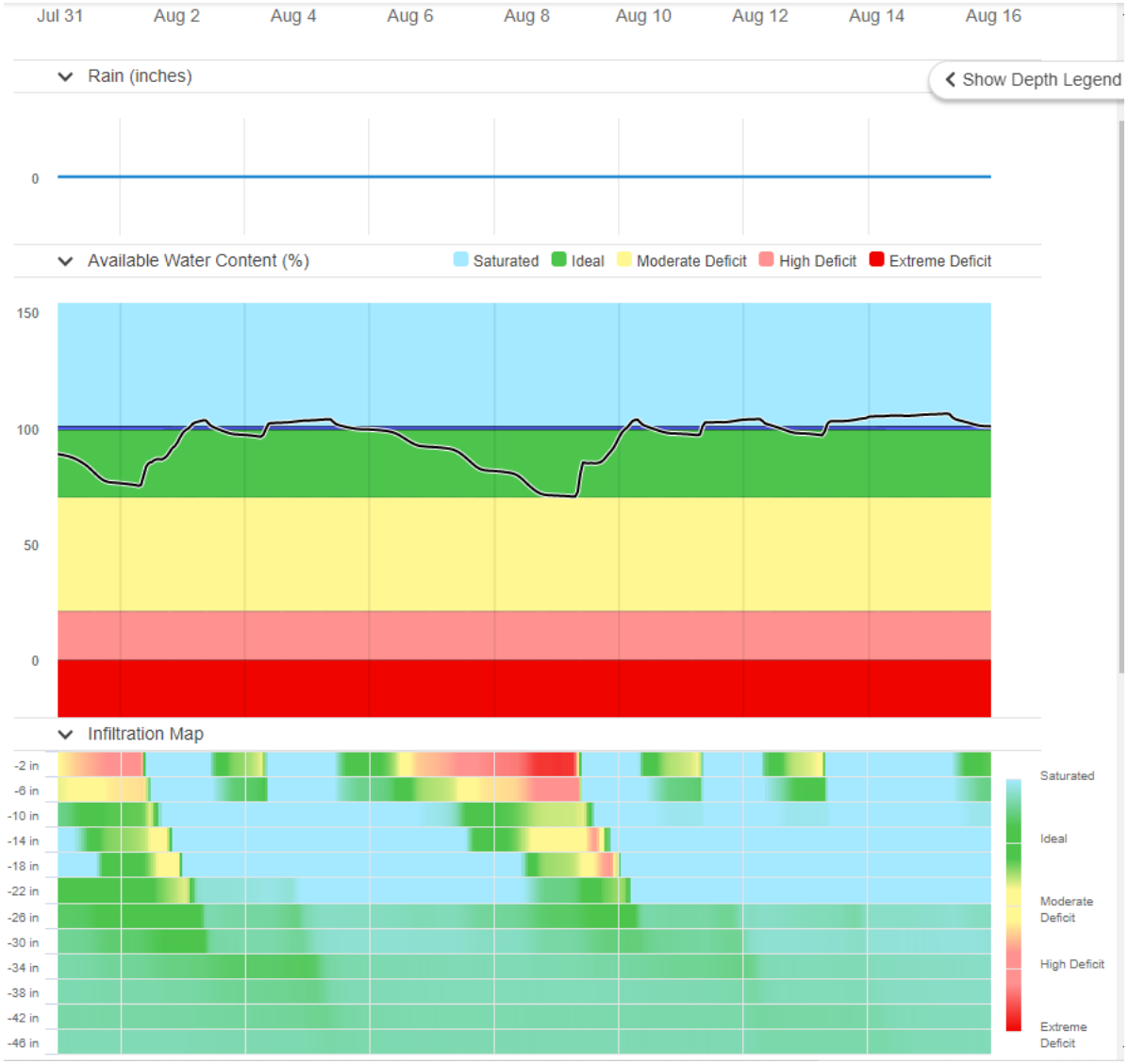
- **Trunk diameter increased more with double line**
- **Aerial imaging showed 15% leaching:**
  - **Increased Chlorophyl content**
  - **Increased NDVI**
  - **Decreased stress**

<u>No treatment differences:</u>

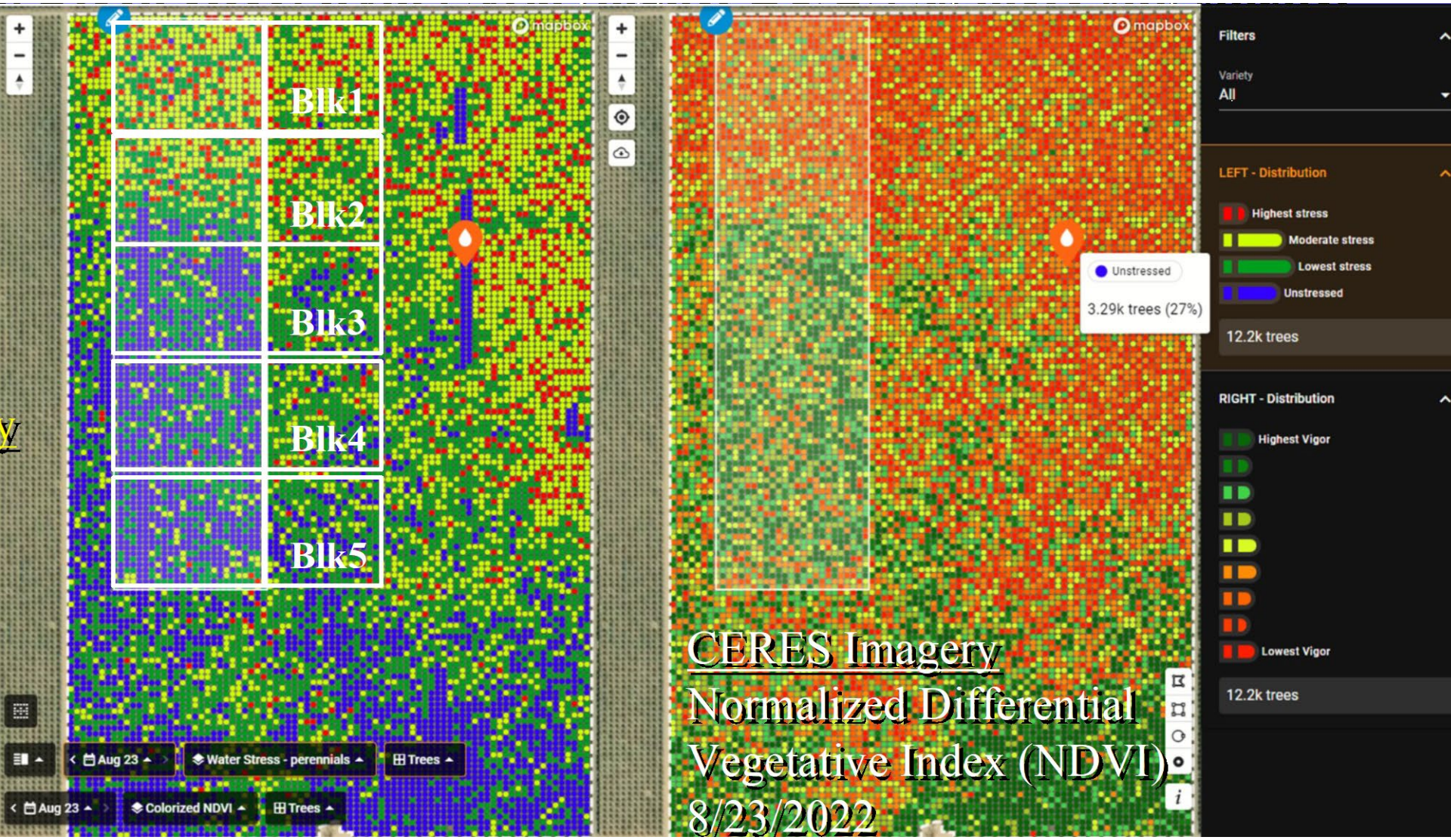
- Leaf analyses

- Yield and edible quality and value

Experimental Results: Semios user interface



Experimental Results: Ceres Imaging



Project Objective and Approach:

Determine best way to maintain soil salinity within acceptable range in saline soils with saline water supplies:

Evaluating:

Double or single drip line +/-

In-season leaching fraction

- **Pulsed in-row winter leaching**

Monitoring:

Real time monitoring tools:

- **in-dwelling irrigation, salinity, trunk growth and water pressure sensors integrated with a weather system to show real time soil water and salinity content, and confirm with:**
- **aerial imaging**
- **soil and leaf samplling**
- **Physiological, nutritional and yield measurements**

Project Cooperators:

Maricopa Ranch:
Clay Beck, Joe Coelho,

Semios:
Jordan Hazell, Anthony Miele

Dellavalle Labratories:
Andrew Koetsier

Ceres Imaging:
Dirk Venn

California Pistachio Research Board

CDFA