Cutting Edge Technologies for Avocado Production

David Crowley
Dept of Environmental Sciences,
University of California, Riverside

New Technologies for Avocado Production

- High Density plantings
  - Mounded rows
  - Growth regulators

- Improved rootstocks for salinity tolerance
  and resistance to Phytophthora root rot

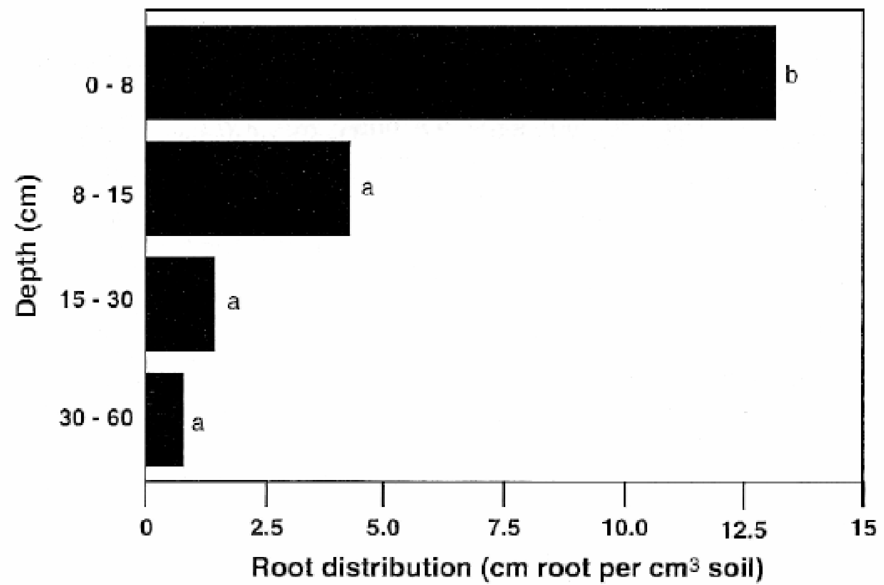
- Use of charcoal (biochar) amendments
  - Improved CEC, pH, bulk density, soil structure
  - Improved water holding, aeration, root growth
  - Increased microbial activity

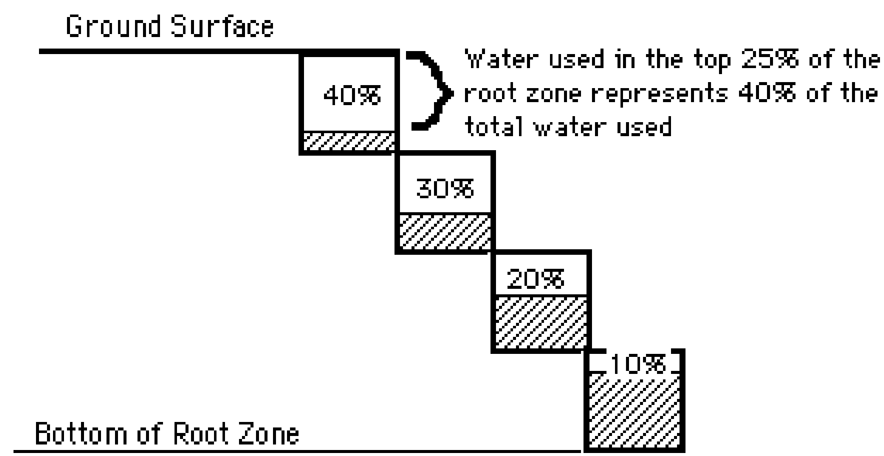
- Soil inoculation with PGPR (plant growth promoting rhizobacteria)
  - Control of phytophthora root rot
  - Stimulation of root growth
    - Improved water use efficiency
    - Improved salinity tolerance

- Online Decision Support Tools
  - Irrigation and Fertilizer Management
  - Neural network based disease and yield forecasting models

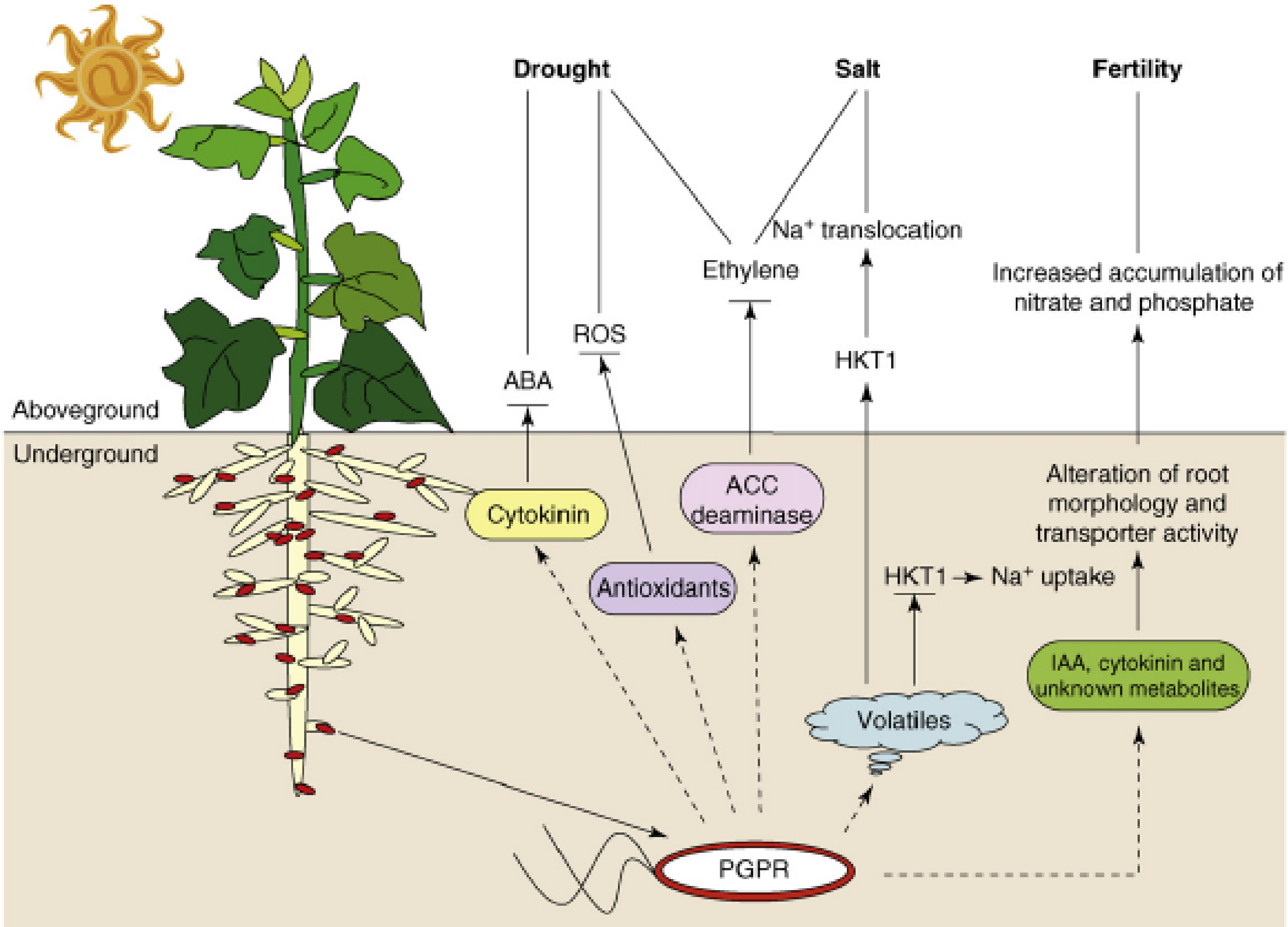

High Density Plantings
Mounded rows with mulch

Root Depth Distribution and Water Use by Avocado





Effects of plant growth promoting rhizosphere bacteria (PGPR) on plant drought and salt stress. Yang et al., 2001



TRENDS in Plant Science

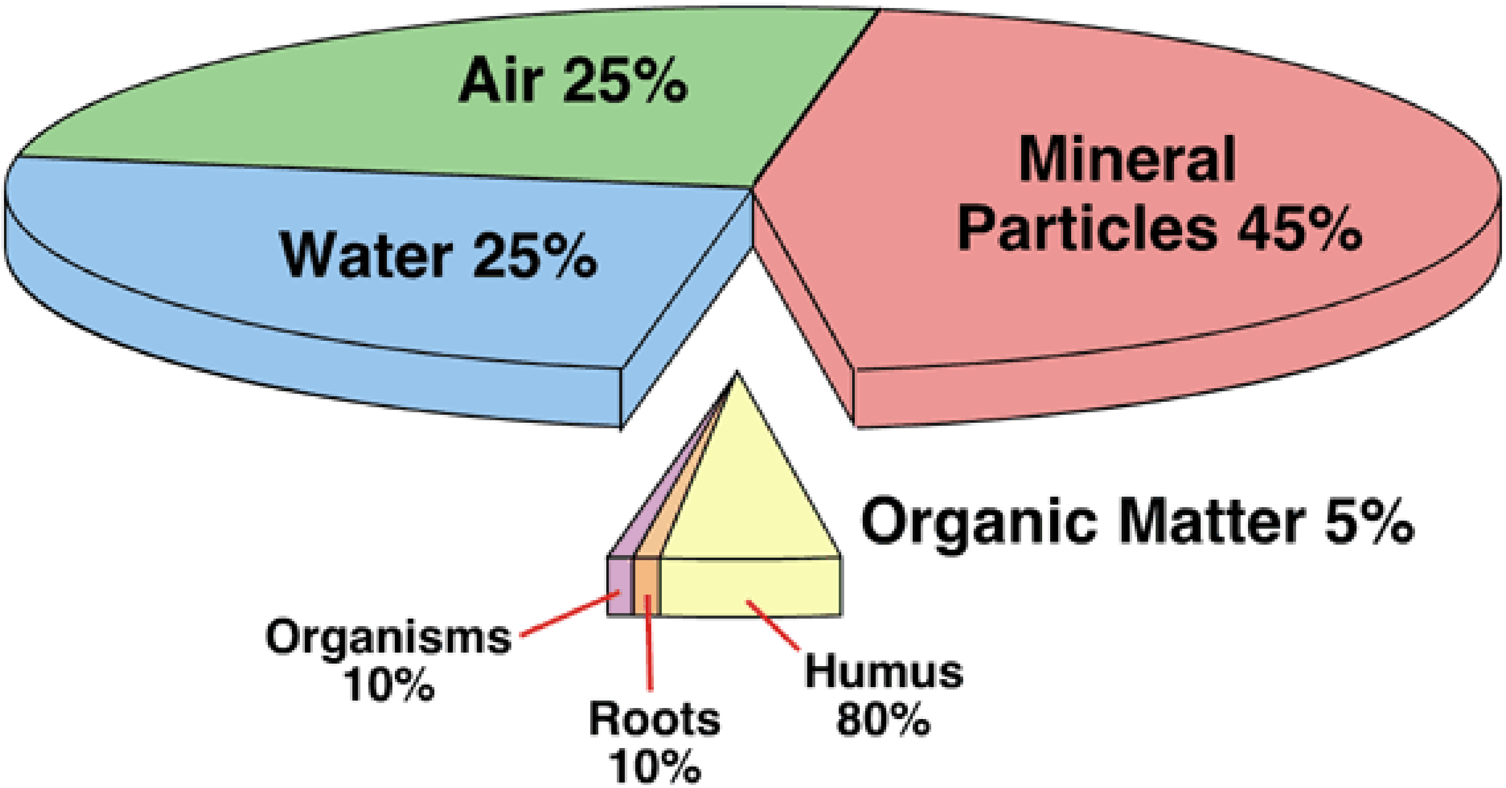
Priorities for California Avocado Production
Soil and Water Management
(Topics for Today)

- Soil physical and chemical properties
  - Root growth

- Irrigation water
  - Salinity
  - Irrigation management

- Results of the CAC Salinity Research Project
  - Root stocks selections
  - Soil and water factors contributing to salinity
  - Computer guided decision support tools

The ideal soil: no stress for air or water, good soil structure, low bulk density, supports beneficial microbial activity, root growth



Soils Used for Avocado Production in California

Physical Properties

Texture	Sandy to Heavy Clay
Bulk Density	1.2 – 1.6 g/cm^3
Porosity	20% to 50%
Stable Aggregates	5% to 30%

Chemical Properties

pH	5 – 8
Cation Exchange	2 – 30 meq / kg
Organic Matter	0.1 – 4%

Search

Enter Keywords [Go]

All NRCS Sites

Browse by Subject

- Soils Home
- National Cooperative Soil Survey (NCSS)
- Archived Soil Surveys
- Status Maps
- Official Soil Series Descriptions (OSD)
- Soil Series Extent Mapping Tool
- Soil Data Mart
- Geospatial Data Gateway
- eFOTG
- National Soil Characterization Data
- Soil Geochemistry Spatial Database
- Soil Quality
- Soil Geography
- Geospatial One Stop

The simple yet powerful way to access and use soil data.

START WSS

Welcome to Web Soil Survey (WSS)

Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information.

Three Basic Steps

1 Define.

Use the Area of Interest tab to define your area of interest.

Click to view larger image

I Want To...

- Start Web Soil Survey (WSS)
- Know the requirements for running Web Soil Survey
- Know whether Web Soil Survey works in my web browser
- Know the Web Soil Survey hours of operation
- Find what areas of the U.S. have soil data

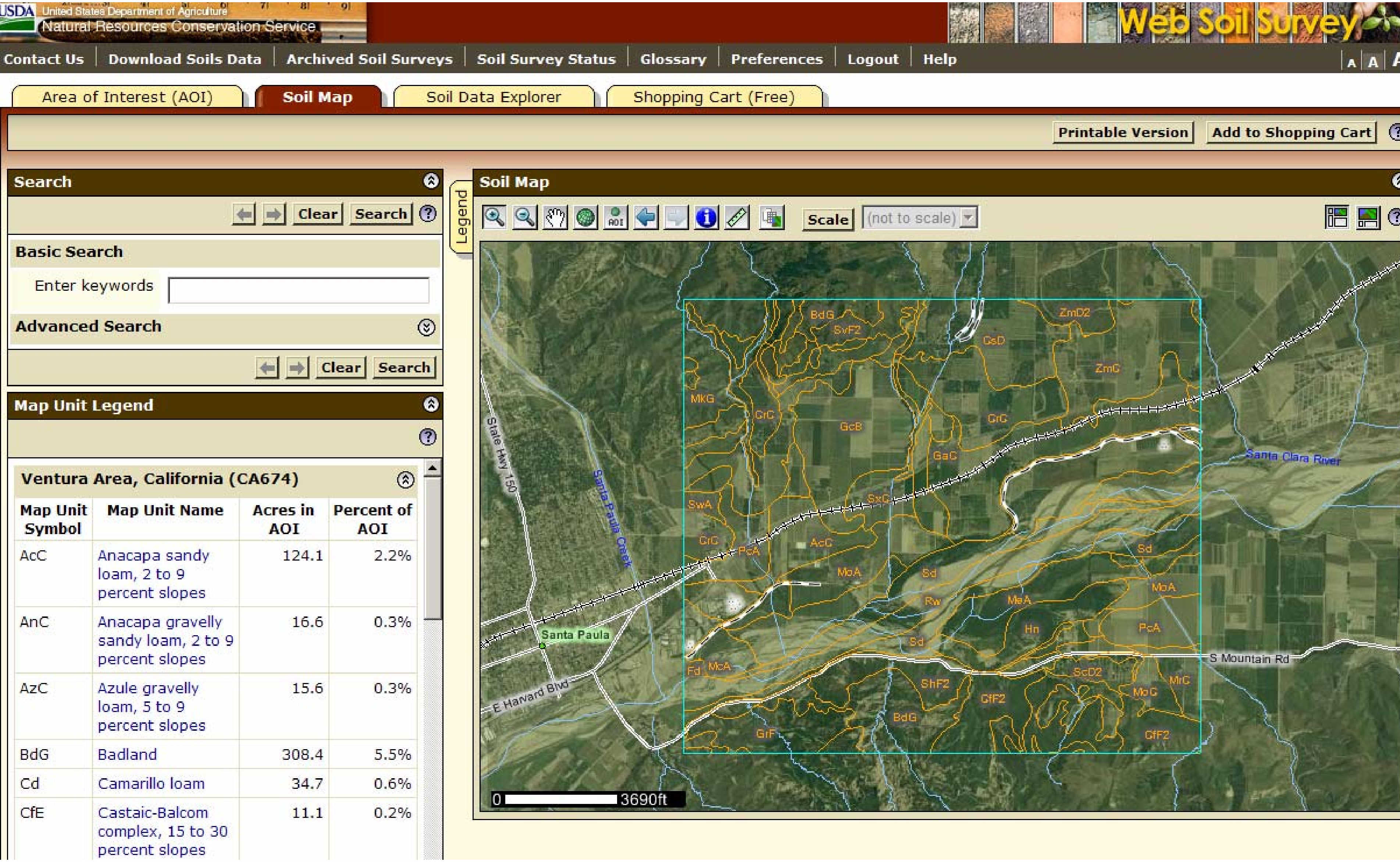
Announcements/Events

- Web Soil Survey 2.1 has been released! View description of new features.

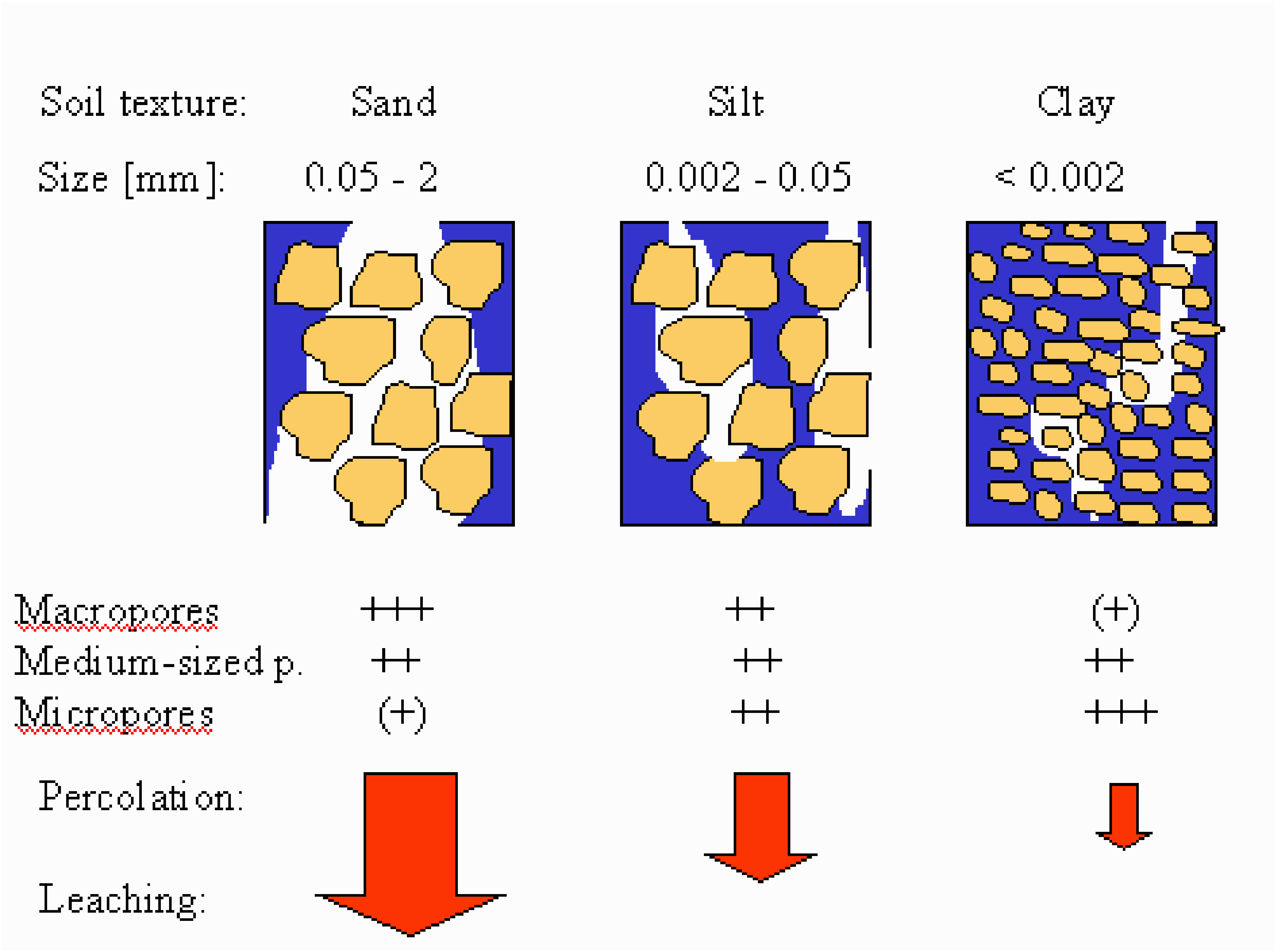
I Want Help With...

- How to use Web Soil Survey
- How to use Web Soil Survey Online Help
- Known Problems and Workarounds
- Frequently Asked Questions

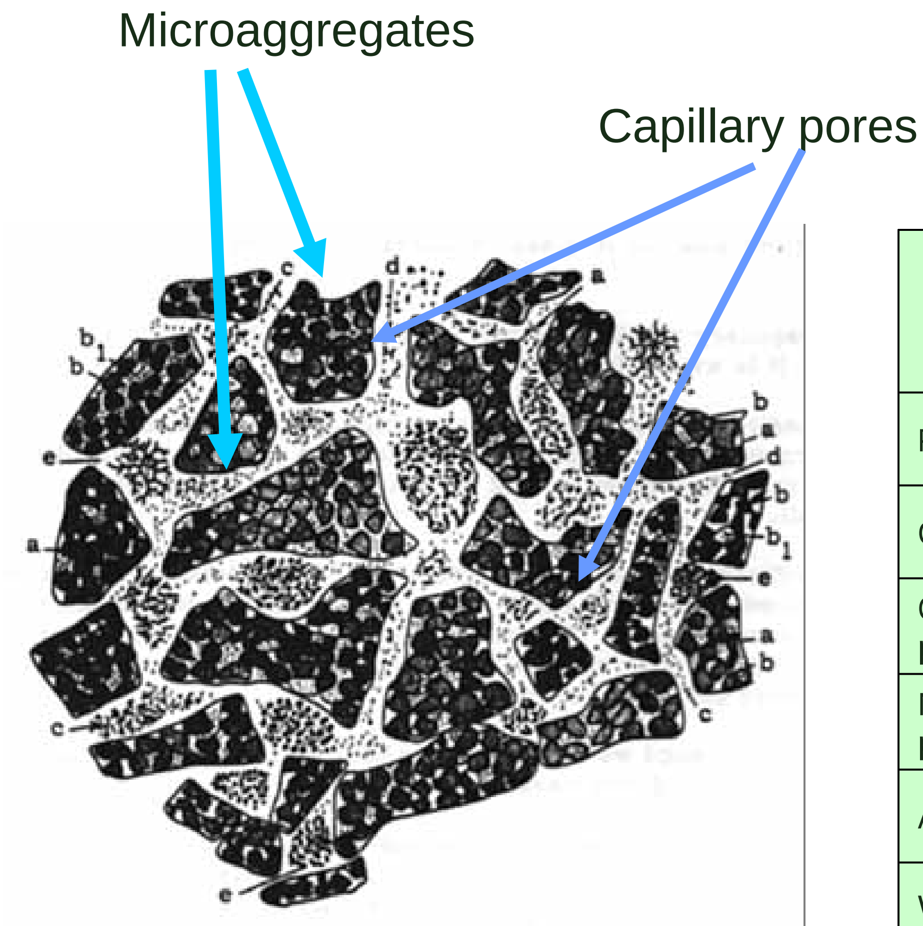
Finding your soil: USDA Web Soil Survey



The Role of Soil Texture (Sand, Silt, Clay)

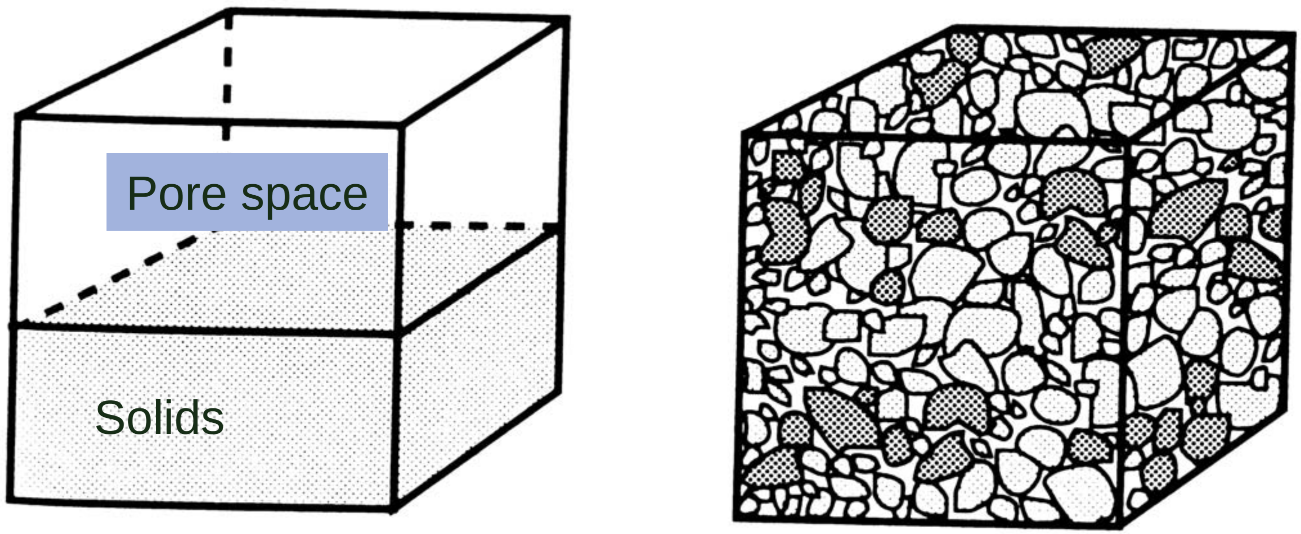


Aggregates: Cemented units of soil particles and organic matter.



	In structureless soil, %	In structured soil, %
Porosity	50	55-60
General porosity	45-48	20-25
Capillary porosity	2-5	30-35
Noncapillary porosity	5	30-40
Air content	3-5	20-25
Water permeability (in mm/hr)	1.6	0.7

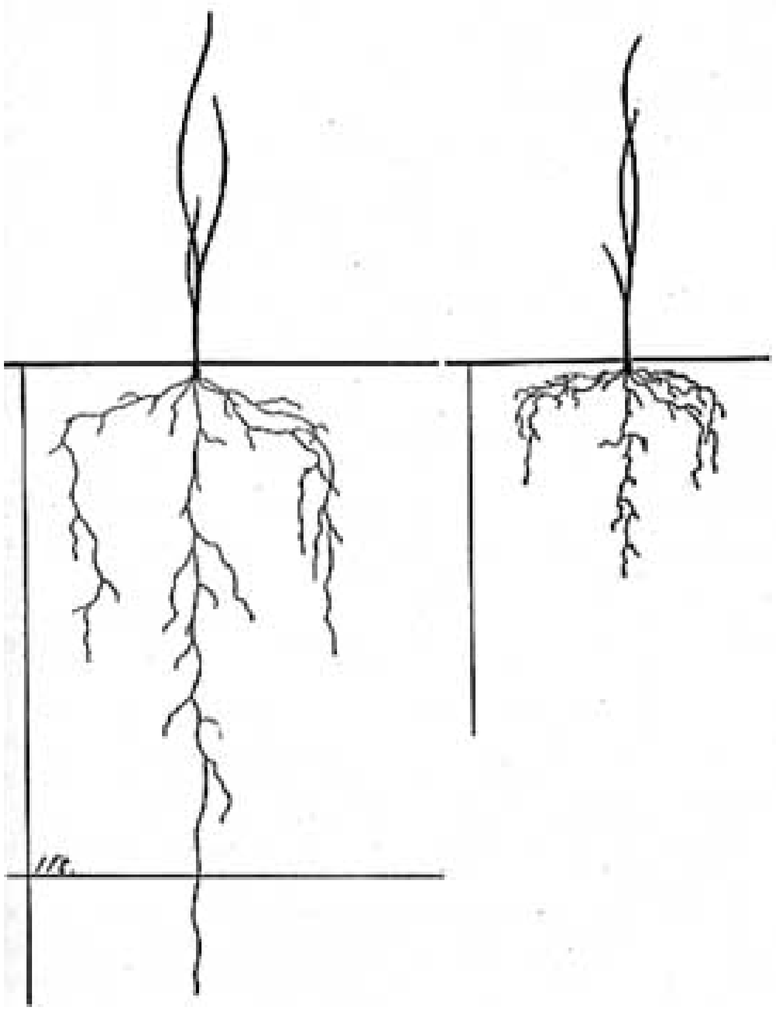
Bulk Density

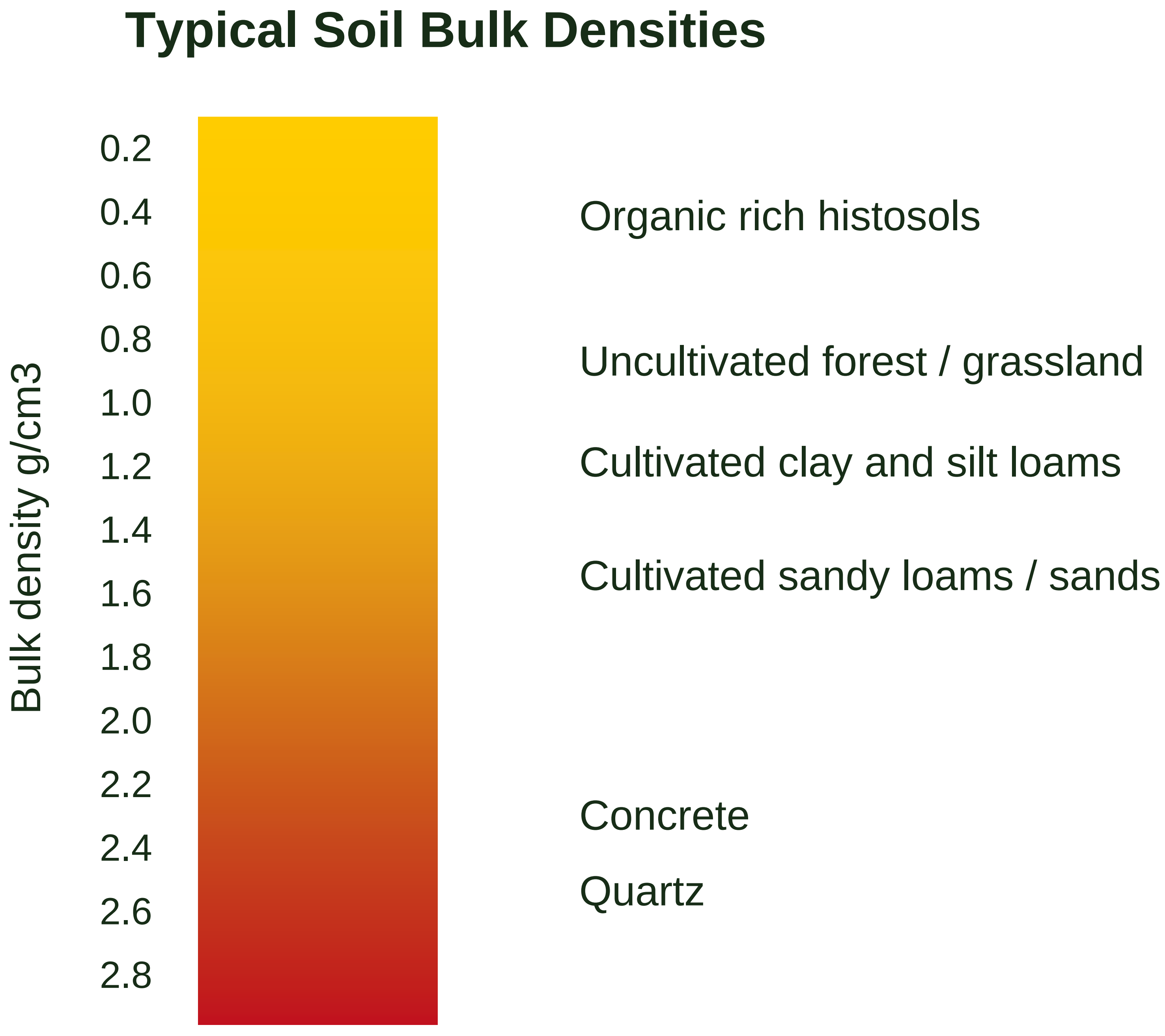


a. Soil volume of solids and pore space

b. Mixture of air, water, minerals, organic matter

Root growth in loose and compacted soils:




Typical Soil Bulk Densities
Bulk density g/cm3
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
Organic rich histosols
Uncultivated forest / grassland
Cultivated clay and silt loams
Cultivated sandy loams / sands
Concrete
Quartz

Bulk density measurements

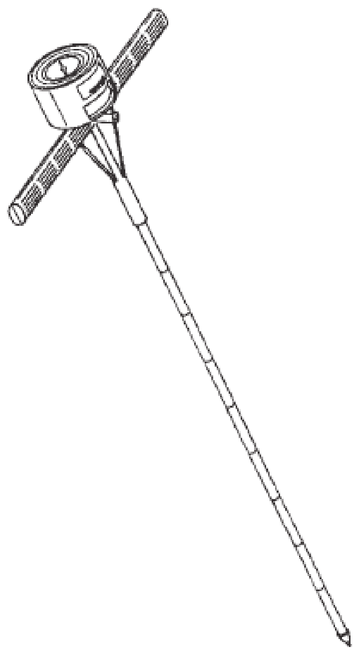
Press steel cylinder into soil to extract an “intact soil core” of known volume

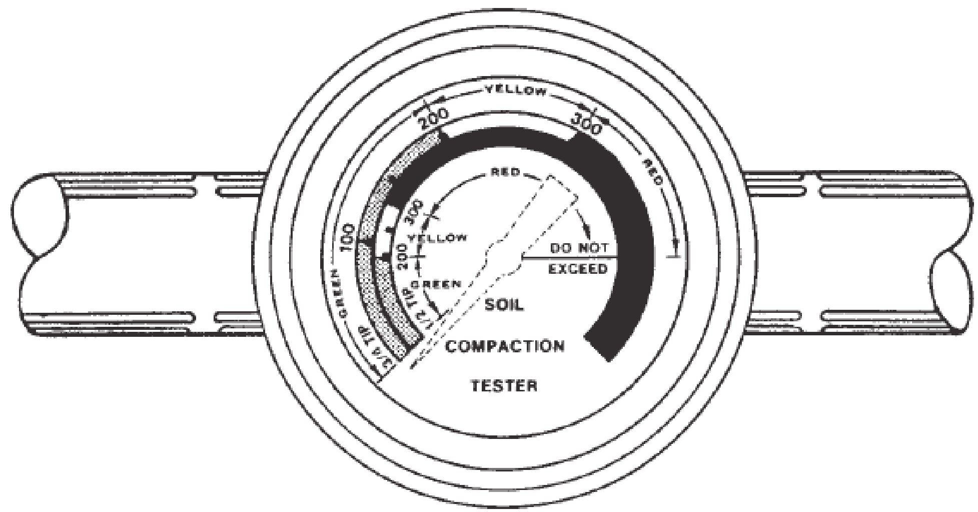
Shave off ends with knife, dry soil core and weigh to obtain weight

Measurement of soil resistance to root penetration

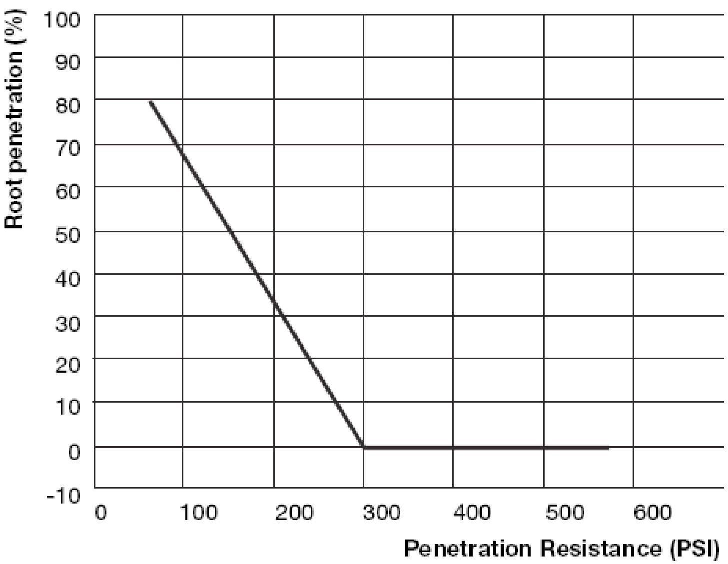
Soil penetrometer

Penetrometer: Soil Compaction Tester





Root Penetration and Soil Resistance



The penetrometer simulates root growth. Root growth decreases linearly with increasing penetration resistance, until practically stopping above 300 psi. Remember, however, that roots may still penetrate soil with a penetration resistance greater than 300 psi if natural cracks and pores are present.

Percentage of measuring points having cone index > 300 psi in top 15 inches	Compaction rating	Subsoiling recommended
< 30	Little-none	No
30-50	Slight	No
50-75	Moderate	Yes
>75	Severe	Yes

Multiple sampling locations (points) need to be measured in the field.

Improving Soil Physical Properties: Bulk Density

Prepare new plantings with mounded rows, include compost or other organic matter

Mulch applications

Gypsum applications in clay soils

Charcoal amendments (Biochar)

Charcoal amendments to soil at 20 tons per acre increase soil organic matter, cation exchange, microbial activity, and plant yields, while storing huge amounts of carbon in soil.

Pot trials using Agrichar™ soil amendment had significant results – doubling the crop yield of soybeans and tripling that of wheat when applied at the rate of 10 tonnes to the hectare.[1]

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Charcoal amendments to avocado soils are being evaluated in Australia and New Zealand as a means to increase soil organic matter and soil fertility.

New Developments in Irrigation and Salinity Management

- Requirement for improved water use efficiency
  - Soil water monitoring
- Irrigation water quality
  - Dealing with salinity
- Soil leaching
- Rootstocks
- Computer decision support tools

Irrigation and Water Use Efficiency

AVOCADOSOURCE.COM Search Tools Site Index: <SELECT PAGE> Avocado Data

Instructions for the Irrigation Scheduling Calculator

English Español

Principles of Irrigation Select a Crop: Avocado

Kc Source: California (New Values) English Units Metric Units

Reference Evapotranspiration (ETo): in./day or period Data Source: <SELECT SOURCE>

Crop Coefficient (Kc): Get Kc for a month <SELECT>

Distribution Uniformity (DU): %

Leaching Requirement (LR): %

Method: Trees per Acre: Tree Spacing by ft.

Number of Emitters per Tree: 1

Surface area under tree canopy (ft^2): (enter only when surface area covered by canopy is less than 65%)

Emitter Output (Gal/Hour):

Grove Size (acres): 1

All fields with yellow boxes must be filled out, white fields are optional.

Calculate Click on 'Calculate' after any changes are made to recompute totals.

Water per tree per day or period: gallons

Watering time per tree per day or period: hours, minutes

Total Water Requirements for Grove: gallons

Allocated Water for Grove: gallons

Shortfall: gallons

Measurement of Soil Water Potential

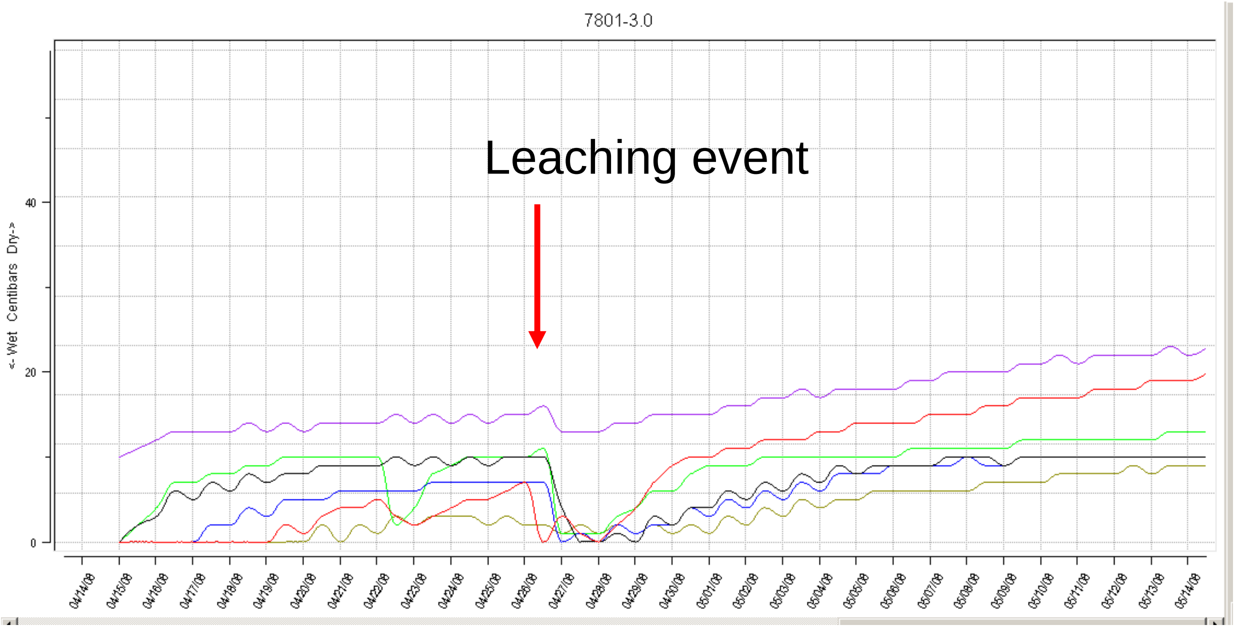
Time Domain Reflectometery (TDR)

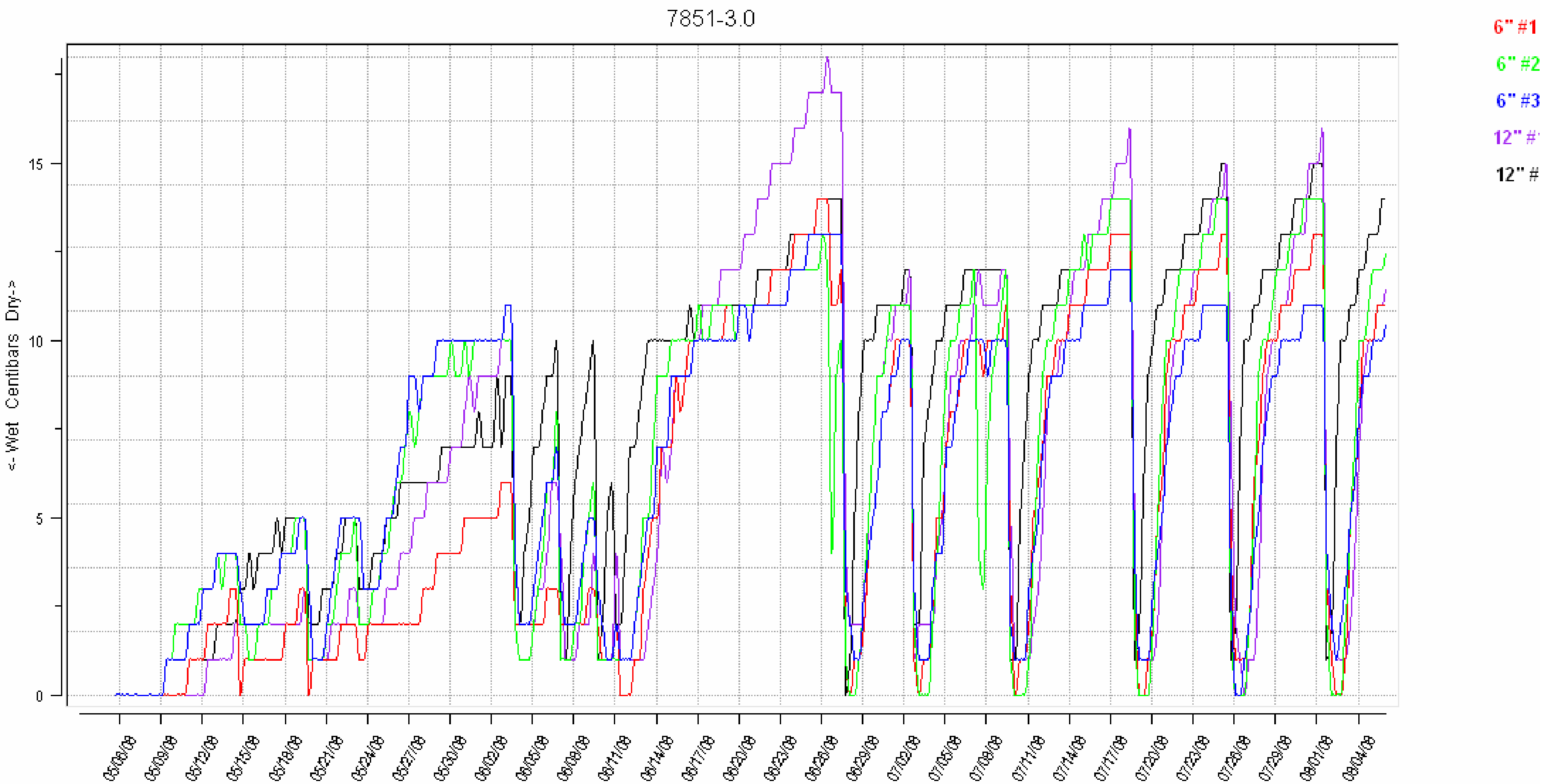
Absorbent Blocks

Tensionmeter

Water Mark Probes

1. Soil temperature
2. Tree 1 6 inch
3. Tree 2 6 inch
4. Tree 3 6 inch
5. Tree 1 12 inch
6. Tree 2 12 inch
7. Tree 3 12 inch
8. Tree 1 24 inch




7851-3.0
<- Wet Centibars Dry->
0
5
10
15
05/06/08
05/09/08
05/12/08
05/15/08
05/18/08
05/21/08
05/24/08
05/27/08
05/30/08
06/02/08
06/05/08
06/08/08
06/11/08
06/14/08
06/17/08
06/20/08
06/23/08
06/26/08
06/29/08
07/02/08
07/05/08
07/08/08
07/11/08
07/14/08
07/17/08
07/20/08
07/23/08
07/26/08
07/29/08
08/01/08
08/04/08
6" #1
6" #2
6" #3
12" #
12" #

Suitability of Water for Irrigation

Quality	Electrical Conductivity (millimhos/cm)	Total Salts (ppm)	Sodium (% of total salts)	SAR	pH
Excellent	0.25	175	20	3	6.5
Good	0.25-0.75	175-525	20-40	3-5	6.5-6.8
Permissible	0.74-2.0	525-1400	40-60	5-10	6.8-7.0
Doubtful	2.0-3.0	1400-2100	60-80	10-15	7.0-8.0
Unsuitable	>3.0	>2100	>80	>15	>8.0

Table D. Metropolitan Water District 2008 Year Average

	Lake Mathews	Lake Perris	Lake Skinner
Silica	8	16	9
Calcium	74	26	55
Magnesium	30	14	22
Sodium	102	62	80
Potassium	5	4	4
Bicarbonate	155	111	136
Sulfate	265	49	170
Chloride	98	86	84
Nitrate	1	0.2	0.3
Total Dis. Salt	661	312	494
Conductance (EC)	1.1	0.57	0.8

Would you put this on your orchard?

How Much Salt is in Your Water?

1 Acre Foot = 1,233,000 Liters

X

TDS = 500 mg / Liter

---

615 kg of TDS Salt

How Much Sodium Chloride is in Your Water?

1 Acre Foot = 1,233,000 Liters

X

Na - 54 to 101 mg/L

Cl - 71 to 96 mg /L

---

66 - 124 kg Na

87 - 118 kg Cl

---

153 - 242 kg NaCl

How Much Salt is in Your Water?

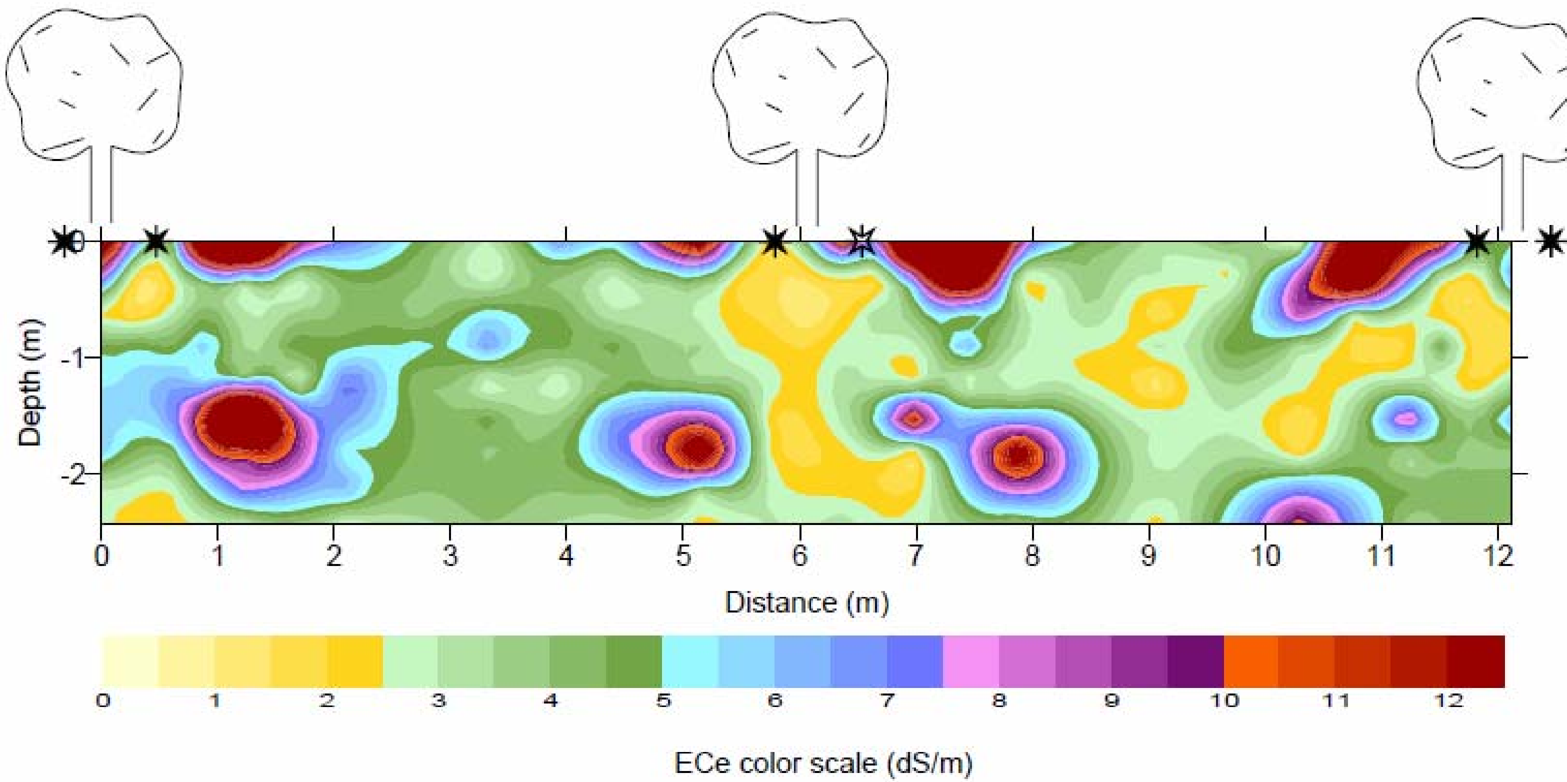
4 Acre Feet:

612 - 968 kg NaCl

2464 kg total dissolved salt

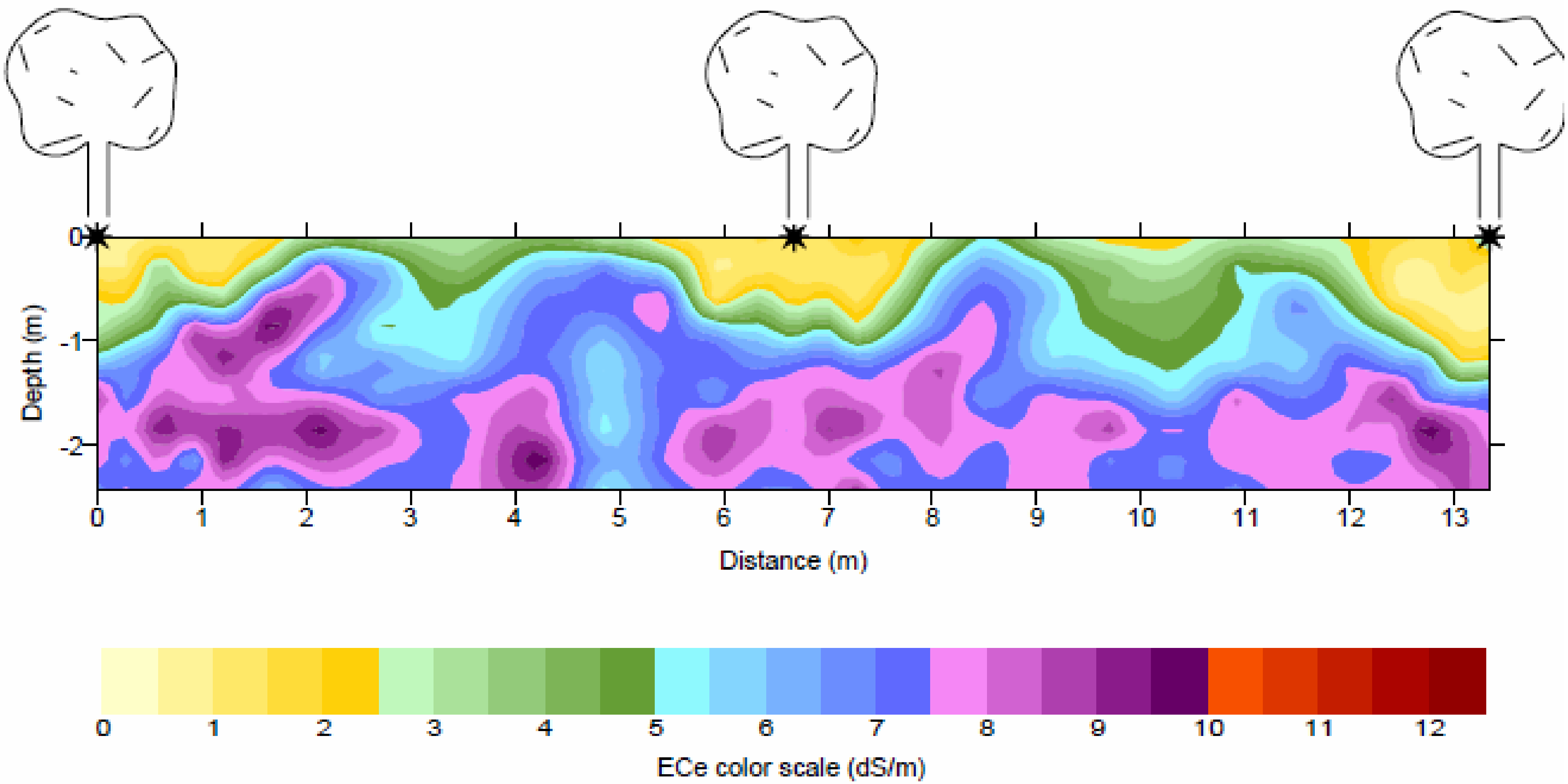

Soil Leaching: Pushing Salt Down

Salt Accumulation in Tree Crop Orchards Using Drip Irrigation



Soil Salinity Accumulation in Orchards with Drip and Micro-spray Irrigation in Arid Areas of California
http://www.itrc.org/reports/salinity/treecropsalinity.pdf ITRC Report No. R 03-005

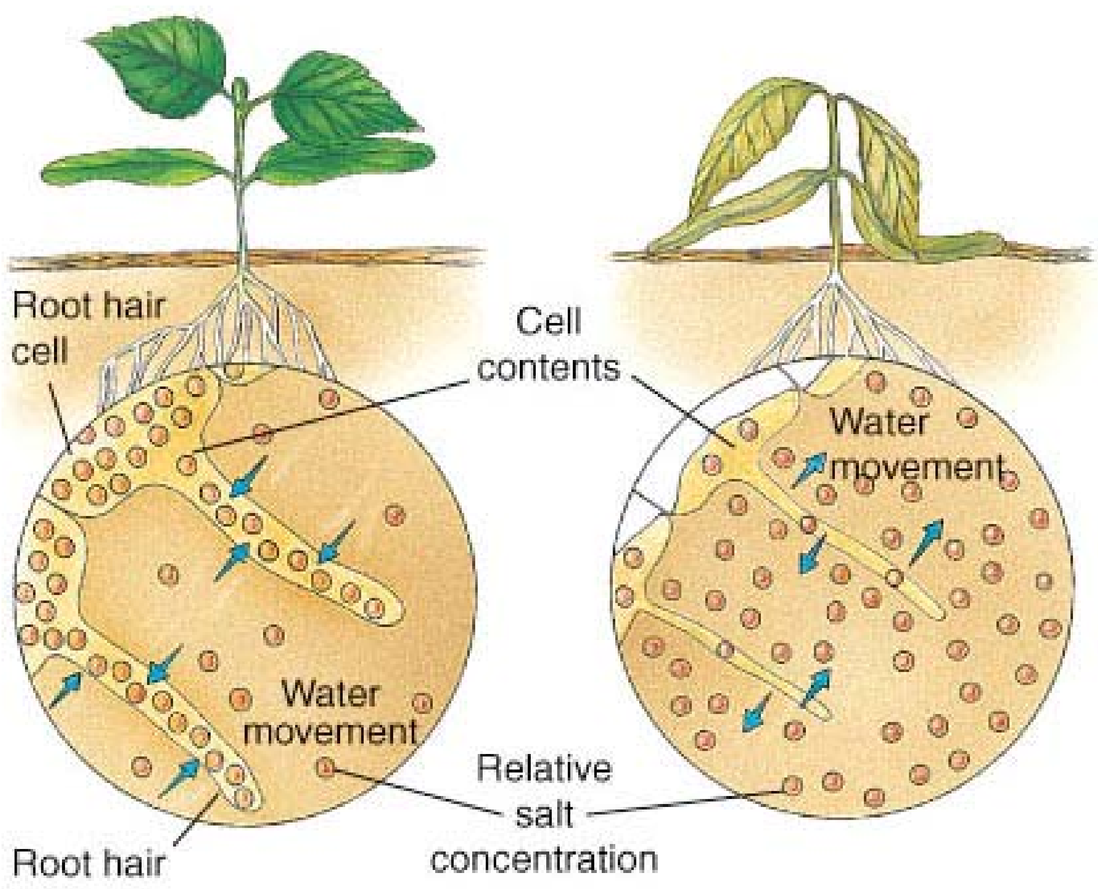
Salt Accumulation in Tree Crop Orchards Using Micro-Spray Irrigation



CDWR 2003

Soil Salinity Accumulation in Orchards with Drip and Micro-spray Irrigation in Arid Areas of California
http://www.itrc.org/reports/salinity/treecropsalinity.pdf ITRC Report No. R 03-005

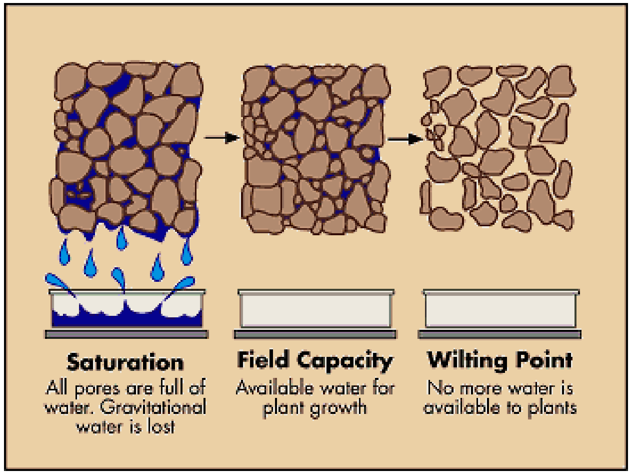
The Problem with Total Dissolved Salt:
High Salt Inhibits Plant Water Uptake



For avocado, this occurs at EC = 4 dS/m

Water enters the plant by c **Salt in the soil sucks water out from the plant roots**

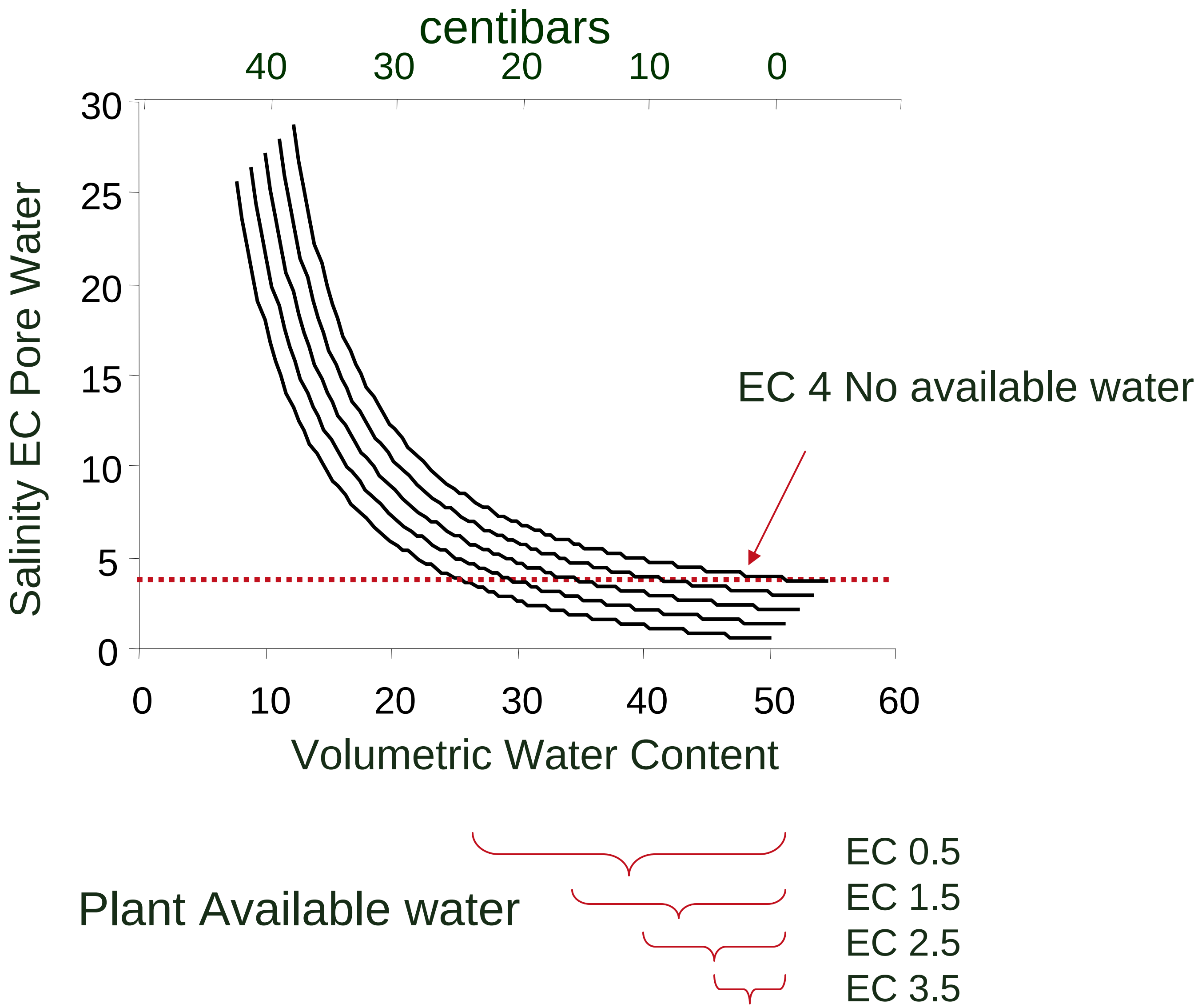
Salinity Calculations for Soil At Different Moisture Levels



Irrigation water EC = 1
Assume no prior accumulation,
Then as soil dries:

Soil Status	Water Content	CentiBars	EC
Saturation	50%	0	1
Field Capacity	25%	3	2
Air dry	10%	40	5
Wilting point	<5%	>100	10

water water everywhere, but nothing ….



Specific Ion Toxicity

Salts in irrigation water include toxic minerals:

Cations	Anions
Calcium Ca^{++}	Sulfate SO_4^{2-}
Magnesium Mg^{++}	Carbonate CO_3^{2-}
Sodium Na^{+}	*Chloride Cl^{-}*
Potassium K^{+}	

Uptake and Distribution of Radiolabeled Chloride and Sodium (Kadman ca 1960s, avocadosource.com)

Chloride

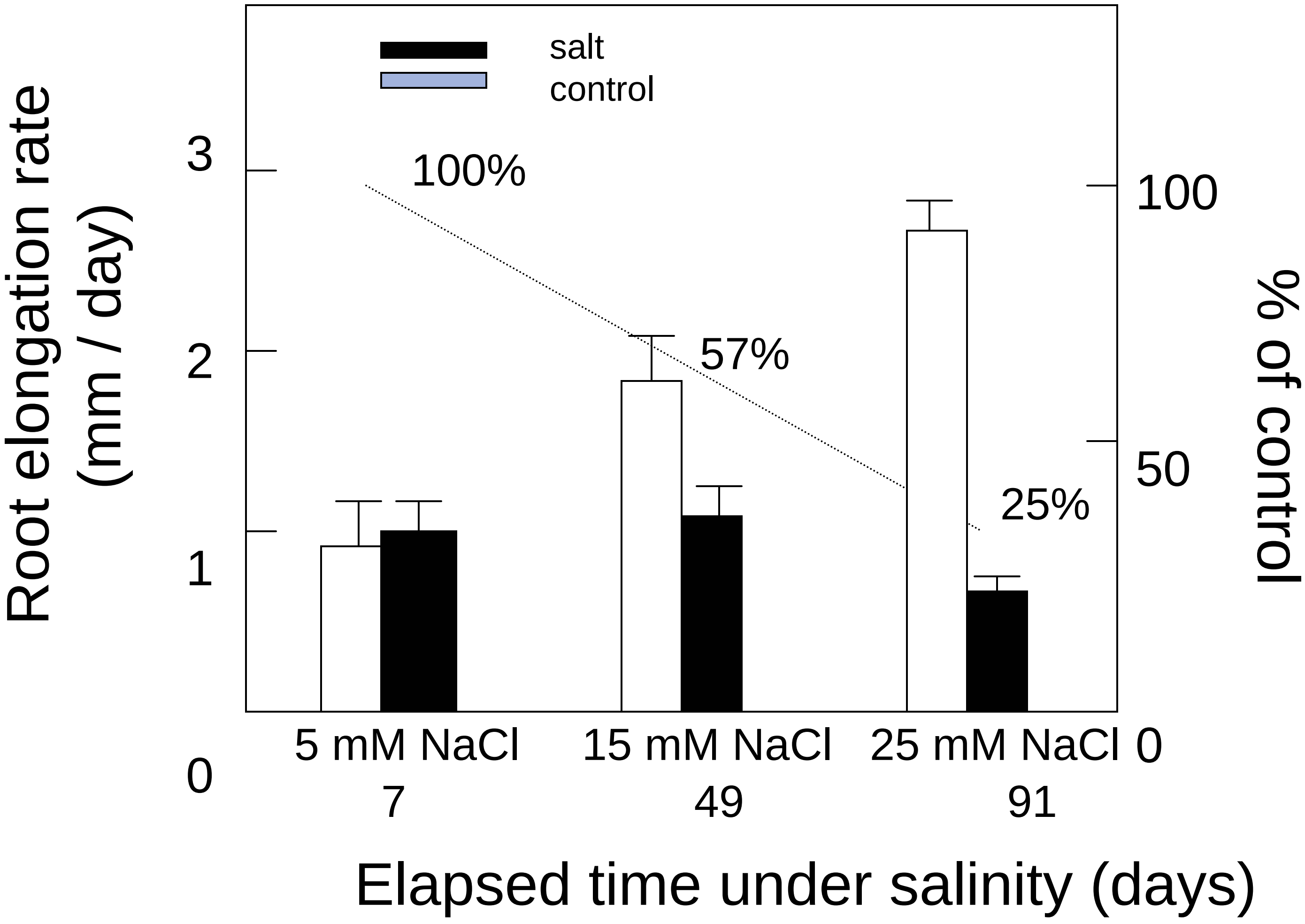
Sodium

Combined Effects of Chloride and Sodium Toxicity

Chloride 0.58%
Sodium 0.35%

Chloride 0.61%

Effects of Chloride Toxicity on Root Growth



Avocado is one of the most saline sensitive crops, and is subject to yield reduction when irrigated with saline irrigation water. This is due to a combined effect of dissolved solids (EC) and chloride toxicities.

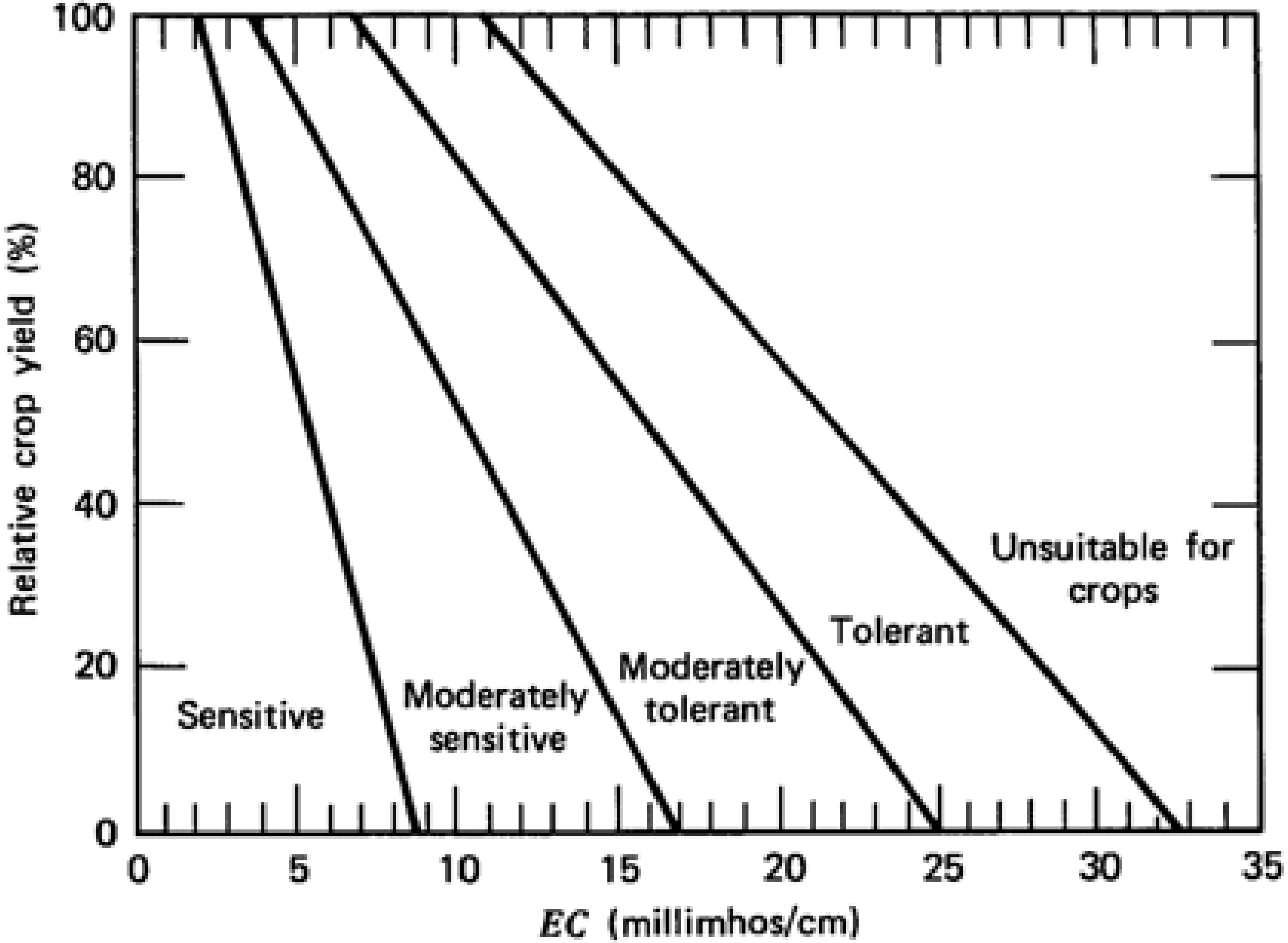


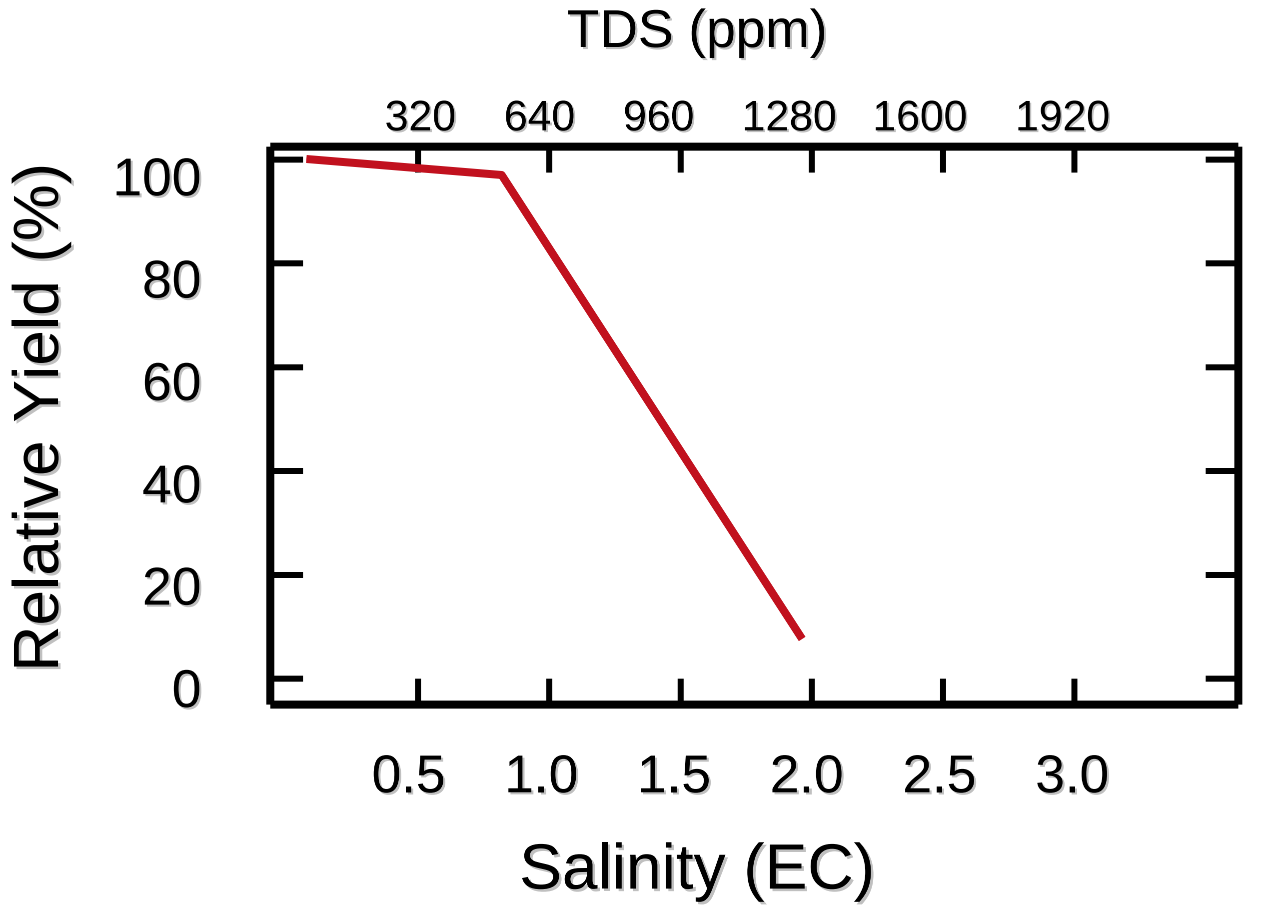
Table 6. Effect of Root Zone Salinity on Crop Productivity of Selected Crops (Carter, 1981).

Crop	**Salinity Threshold (saturated paste EC, mmho/cm)**	**% Productivity Decrease per mmho/cm Increase**
Alfalfa	2.0	7.3
Barley	8.0	5.0
Beans	1.0	18.9
Birdsfoot Trefoil	5.0	10.0
Clover - red	1.5	12.0
Corn - grain	1.7	12.0
Fescue	3.9	5.3
Flax	1.7	12.0
Potatoes	1.7	12.0
Perennial ryegrass	5.6	7.6
Soybeans	5.0	20.0
Strawberry	1.0	33.3
Wheat	6.0	7.1
Wheatgrass - Crested	3.5	4.0
Wheatgrass - Tall	7.5	4.2

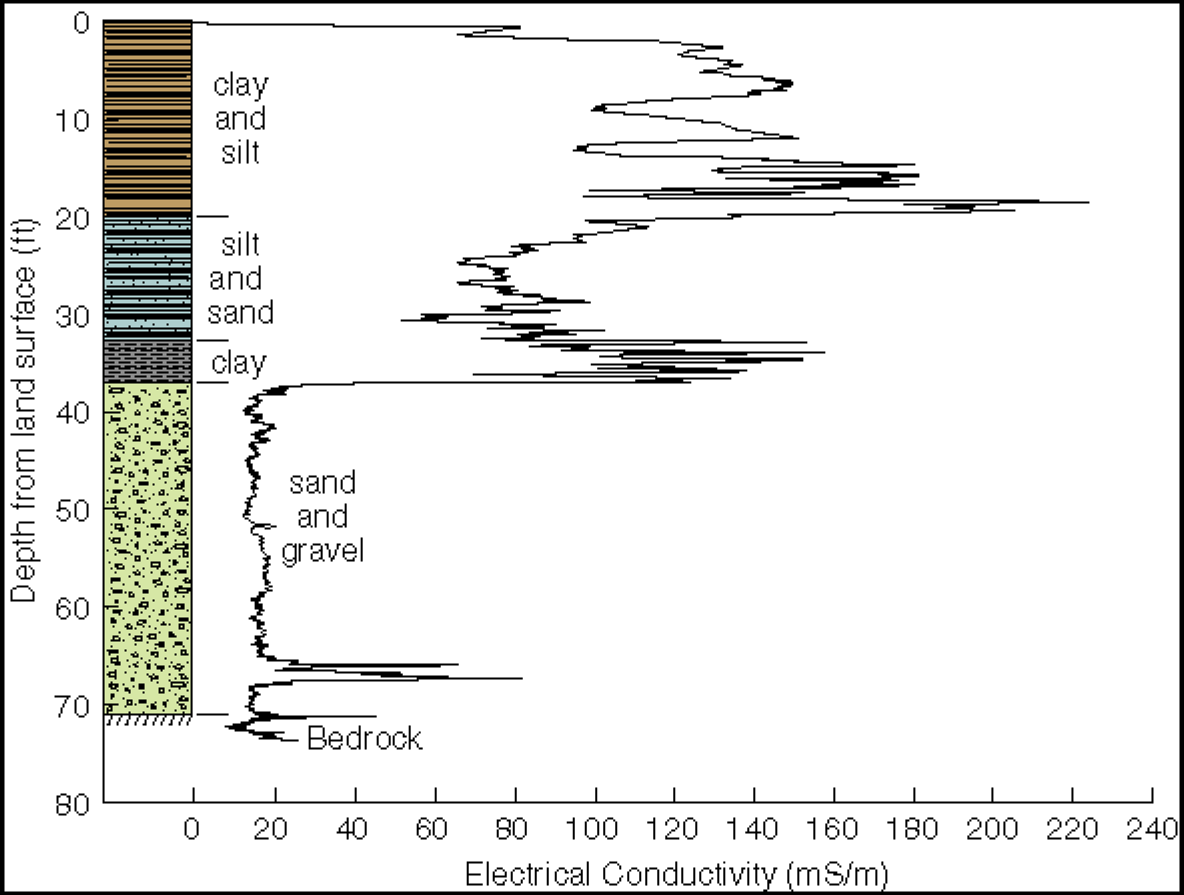
http://www.umanitoba.ca/afs/agronomists_conf/2002/pdf/cavers.pdf

Avocado Yield Function for Irrigation Water Salinity

Oster and Arpaia, J. Am Soc. Hort Sci. 2007



Measuring Salinity: Electrical Conductivity



Units for measuring salinity, and conversion factors.

Conversion factors relating total dissolved salts or pure NaCl to an electrical conductivity (EC) of 1 dS/m (1 deciSiemen/metre) are given, along with equivalent units of various types, old and new.
The conversion of EC of 1 dS/m to total dissovled salts (640 mg/L) assumes a composition of salts that is common in groundwater across the world. The exact factor varies from 530 (if the salt is predominantly NaCl) to 900 (if the salts are formed predominantly from divalent ions).

Measurement and units	Application	1 dS/m is equal to:	Equivalent units
Conductivity (dS/m)	soils	1	1 dS/m = 1 mS/cm = 1 mmho/cm
Conductivity (µS/cm)	irrigation and river water	1000 µS/cm	1 µS/cm = 1 µmho/cm
Total dissolved salts (mg/L)	irrigation and river water	640 mg/L (approx.)	1 mg/L = 1 mg/kg = 1 ppm
Molarity of NaCl (mM)	laboratory	10 mM	1 mM = 1 mmol/L

TDS/Conductivity/Salinity Pen

Collect Soil Cores

0-6”, 6-12”, 12-18”

Prepare 2:1 Water:Soil Extracts

Distilled Water

Measure EC

Multiply x 4 (to estimate EC to soil EC at Field Capacity)

If EC > 0.5 for 2:1 water extract then it is time to leach (equivalent to an EC of 2.0 at field capacity)

Leaching Fraction

$$LR = \frac{ECiw}{5 * EC_{ts} - EC_{iw}}$$

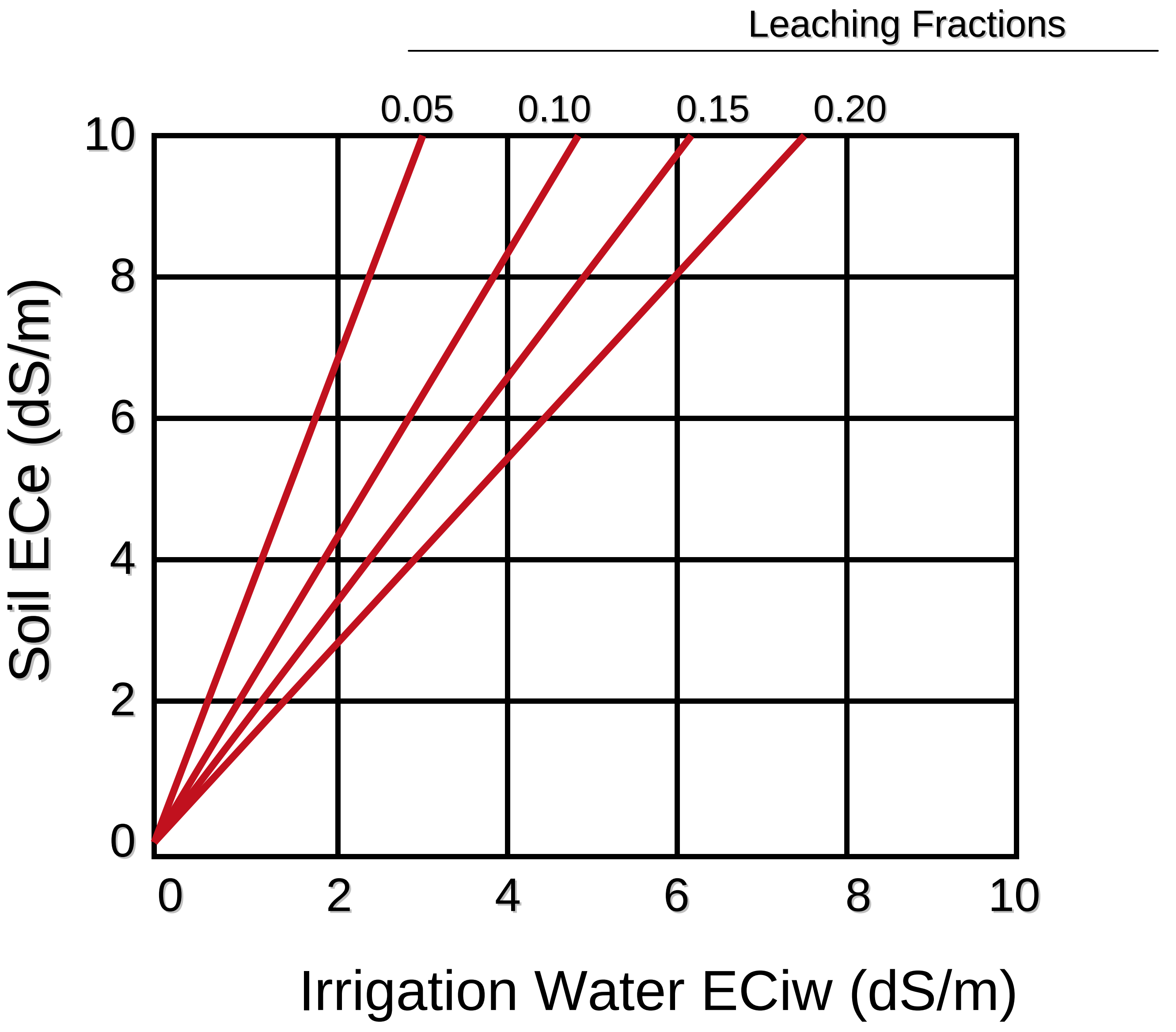
For EC_{ts} 0.67 for avocado and EC 1 irrigation water

$$LR = \frac{1.0}{5 * 0.67 - 1} = .42$$

EC_{ts} = EC threshold sensitivity
EC_{iw} = EC irrigation water

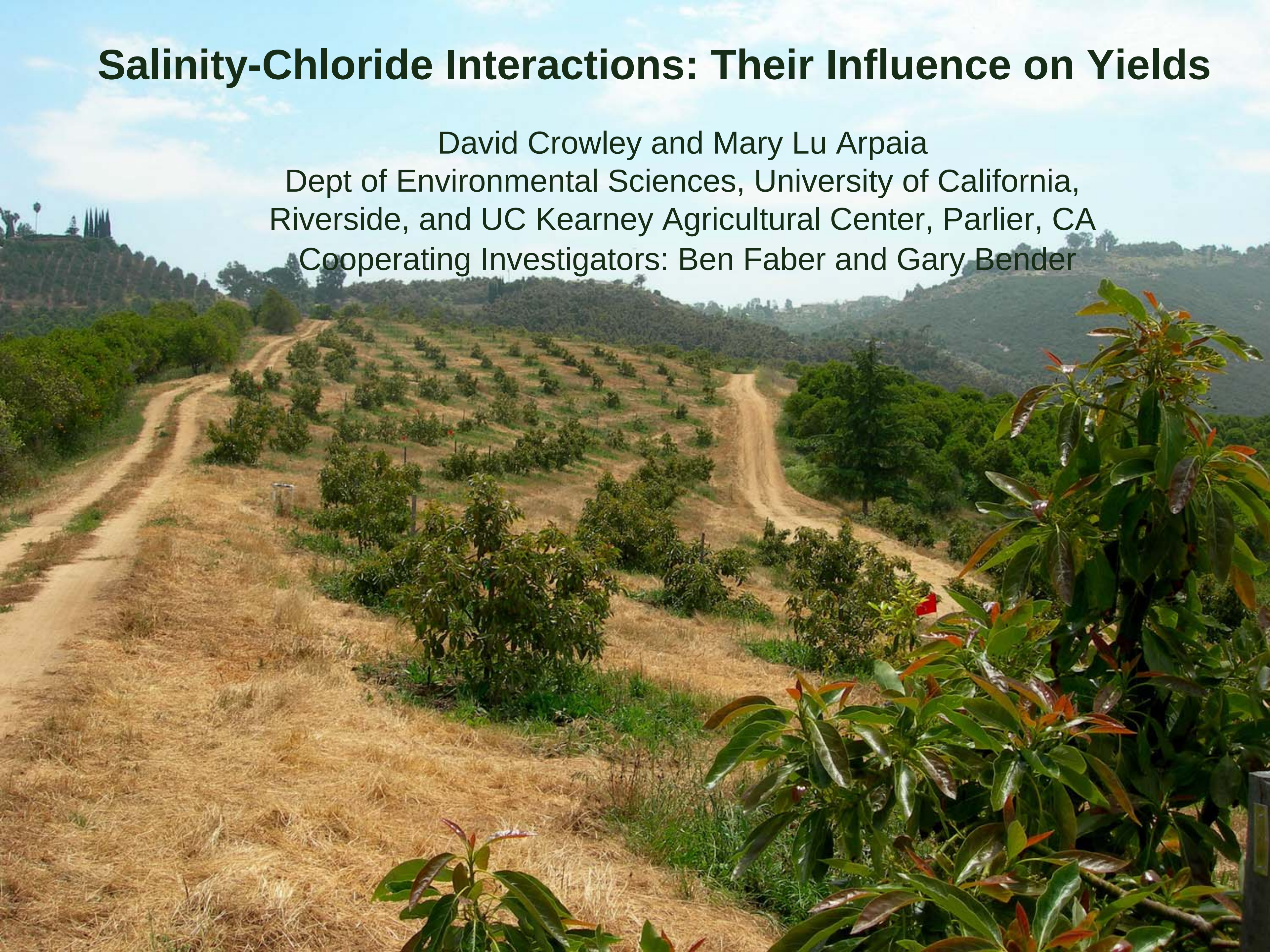
Rhoades 1974

Leaching Fraction



Salinity-Chloride Interactions: Their Influence on Yields

David Crowley and Mary Lu Arpaia
Dept of Environmental Sciences, University of California, Riverside, and UC Kearney Agricultural Center, Parlier, CA
Cooperating Investigators: Ben Faber and Gary Bender



Current Research

Salinity – Chloride Interactions and Their Effects on Avocado Yields

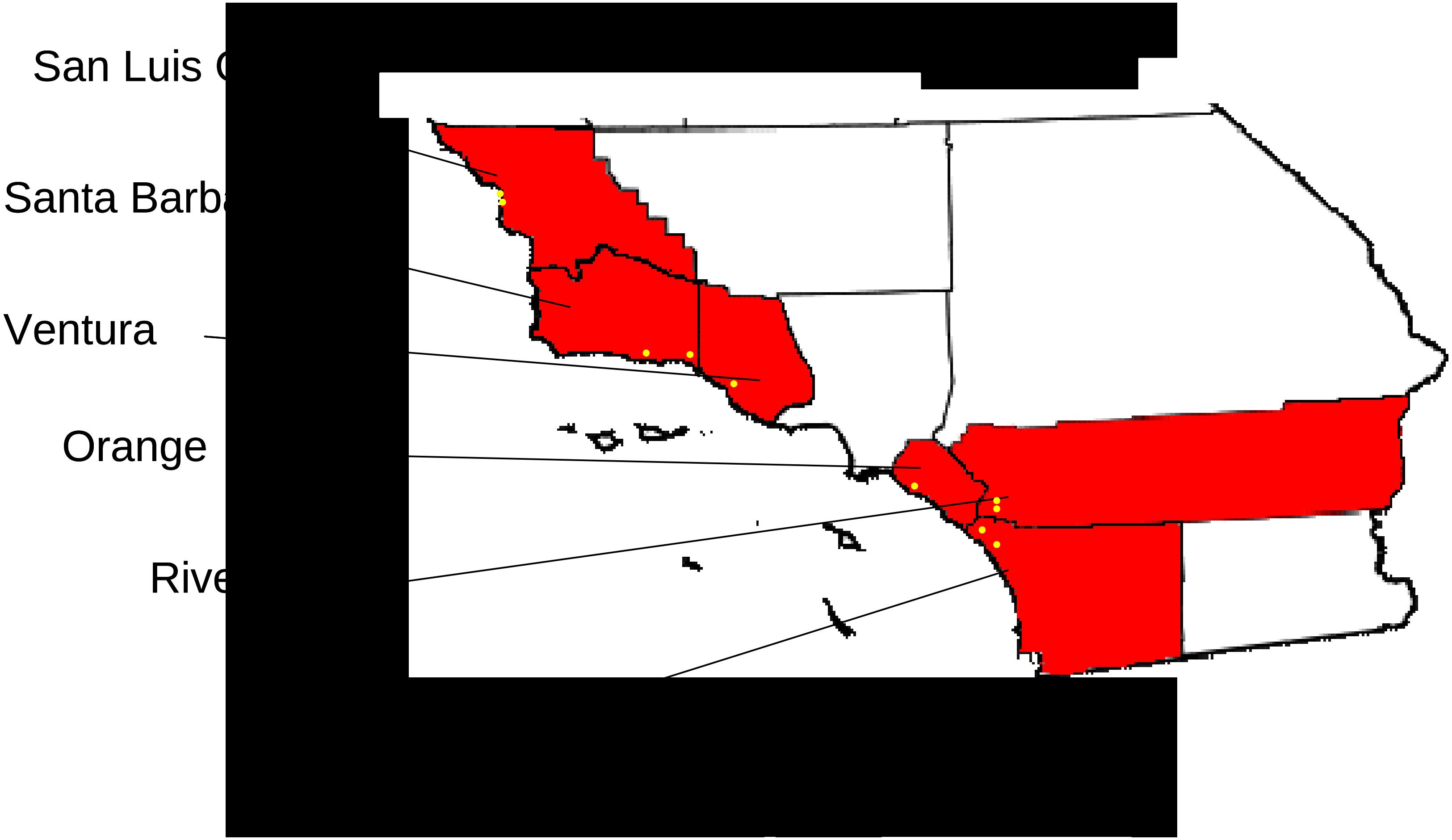
Objectives:

1. **Examine salinity effects on the yields of avocado trees across the main production areas in S. California.**

2. **Compare salinity performance of the major rootstocks now being used for avocado production.**

3. **Evaluate the specific ion toxicity effects of chloride and sodium on root growth.**

Orchard Locations



Rootstocks: Duke 7, Toro Canyon, Dusa, Thomas, Mexican

Experimental Variables Analyzed for each Location

Soils Data	Management	Rootstock Performance
Texture (clay)	Irrigation water quality	Fruit Yield
Salinity	Irrigation scheduling	Macronutrient uptake N,P,K
pH	Leaching	Micronutrients
Organic matter	Fertilization	Root growth
Alkalinity	Canopy management	Phytophthora
Hydraulic conductivity	Use of mulches	Alternate bearing patterns


Steve Smith, Rancho Mupu
Ventura


Lyle Snow Orchard
Ventura


Derek Knobel, Rancho Mission Viejo
Orange


Pete Miller Orchard
Santa Barbara


Deardorff Orchard
Riverside


Ed McFadden, Rancho Simpatica
Ventura


Rick Carey Orchard
San Diego


Van der Kar Orchard
Santa Barbara


Tyson Davis Orchard
San Luis Obispo


Woodworth Orchard
Riverside

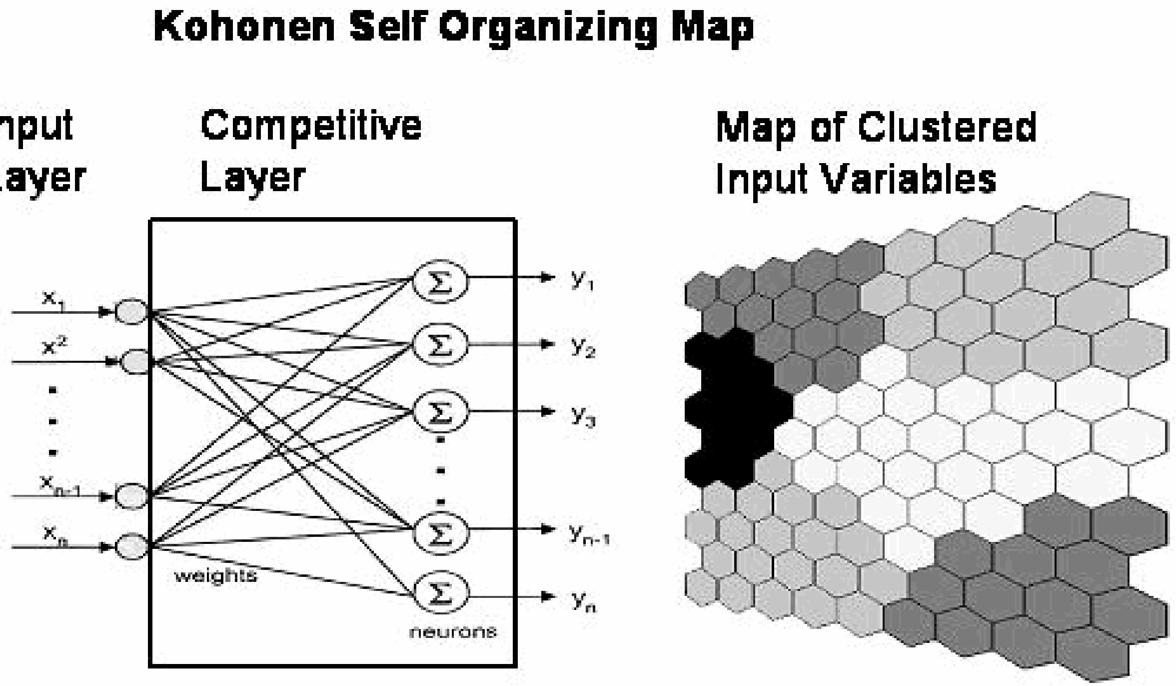

Duncan Abbott Orchard
Santa Barbara


Staller Orchard
San Luis Obispo

Application of Artificial Neural Networks for Examining Relationships of Plant, Soil, and Water Variables Affecting Avocado Yields

pH
% clay

salinity
chloride
yield



Quantification of Root Growth Responses to Salinity Stress

Variables analyzed

- Root biomass / root length measurements
- 0-6, 6-12, and 12-18 inch soil cores
- Soil chemical and physical analyses
- Water EC, Cl

ANN Model Output:

- Rootstock variations in root mass and depth distribution
- Reductions in root weight in relation to chloride and soil salinity

Quantification of Chloride Uptake in Relation to Irrigation Water and Soil Salinity Management

Variables Analyzed:

- Soil Cl, EC, clay content, pH
- Rootstock
- Root length
- Irrigation water quality EC, Cl

Model Output: Leaf chloride content

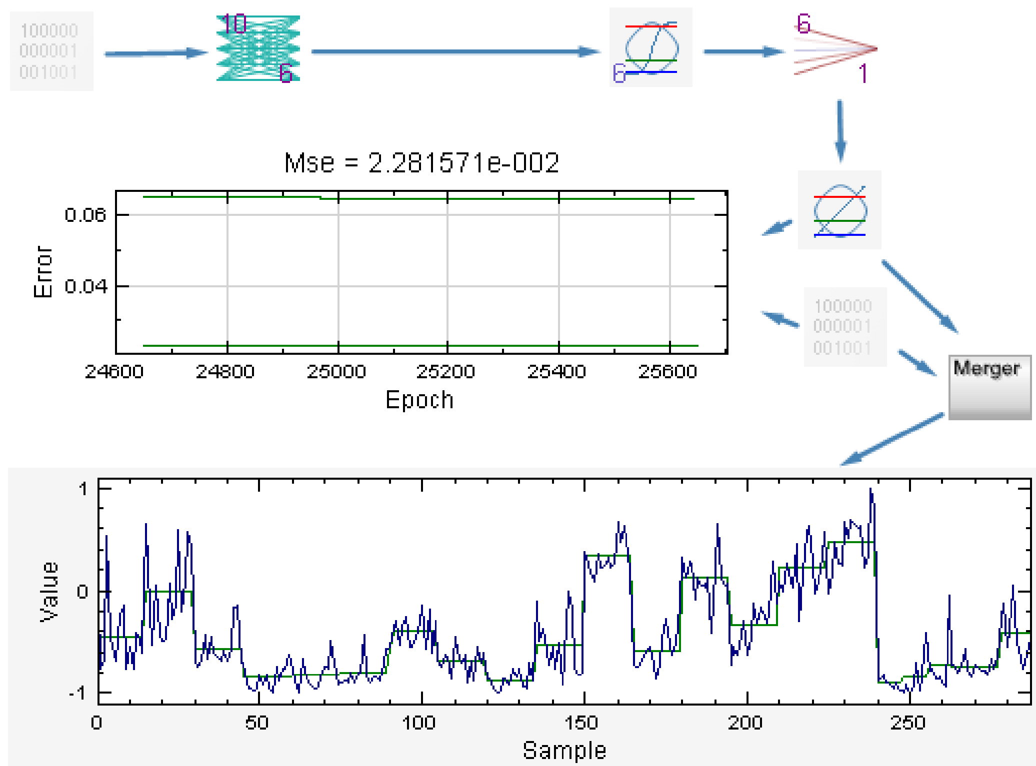
ANN Predictive Modeling of Soil and Water Factors on Avocado Leaf Chloride Content, Root Growth and Yields

Model Training

Input data

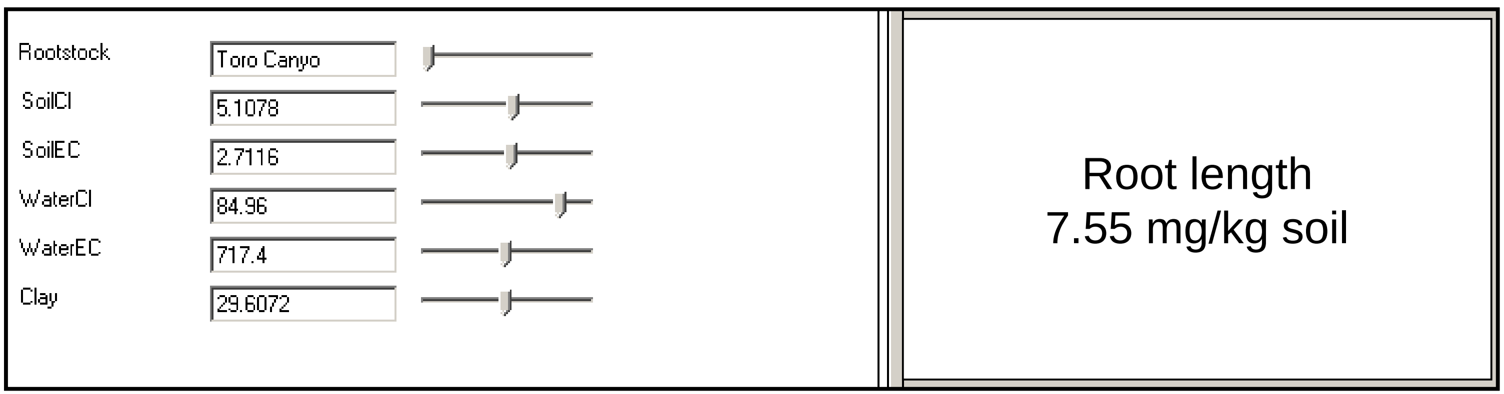
Model error

Data fit

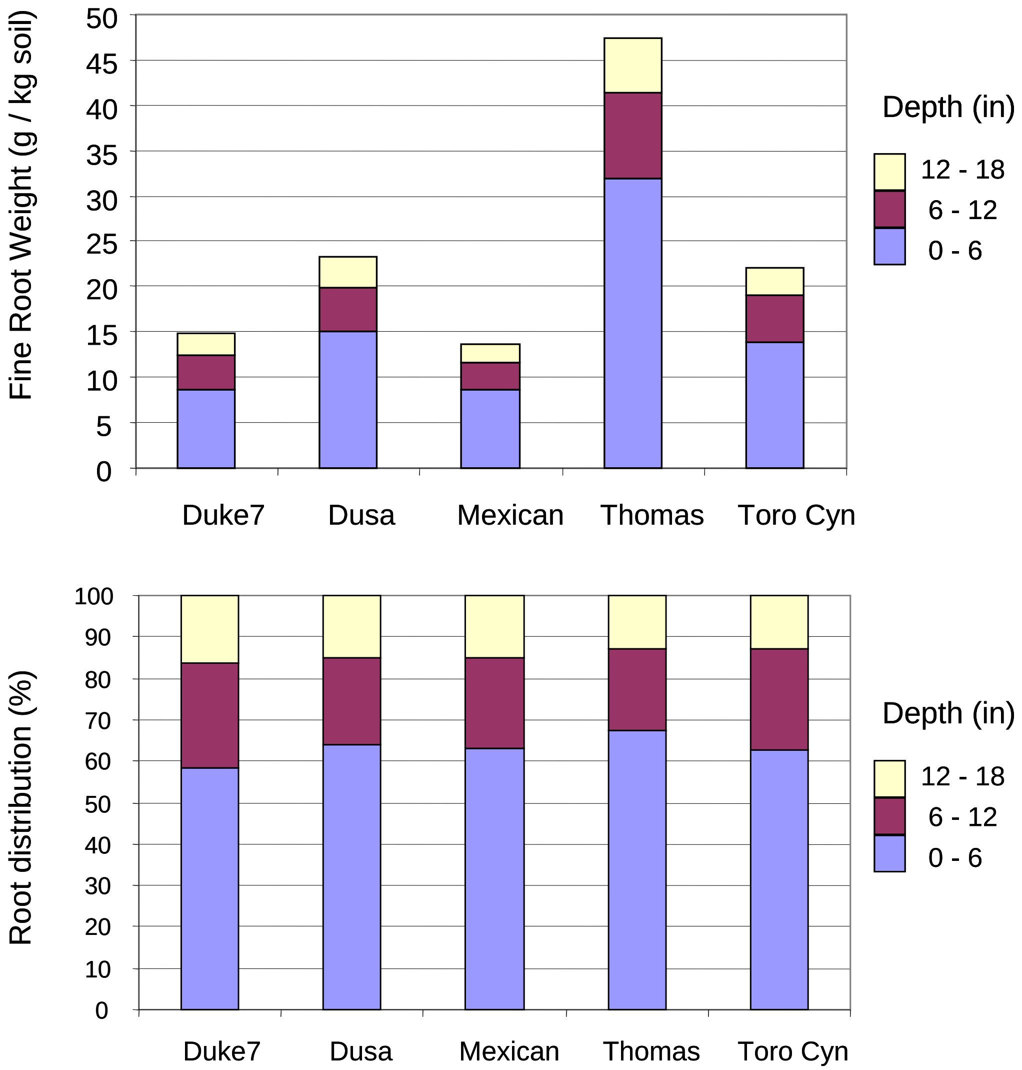


ANN Model Output and Sensitivity Analysis of Soil and Water Factors Affecting Root Length

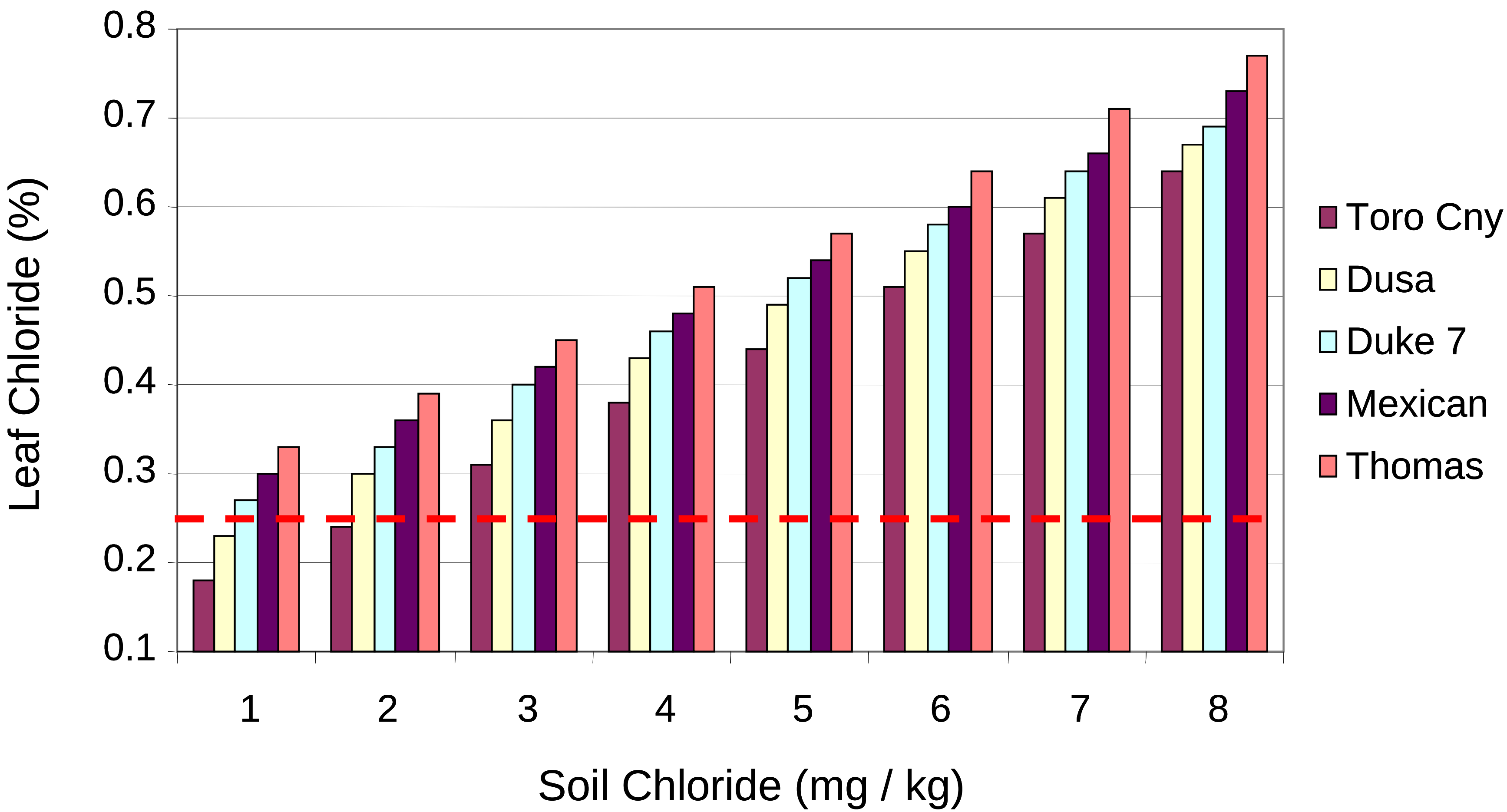
Variable | Value | Slide bar adjustment | Predicted output variable value



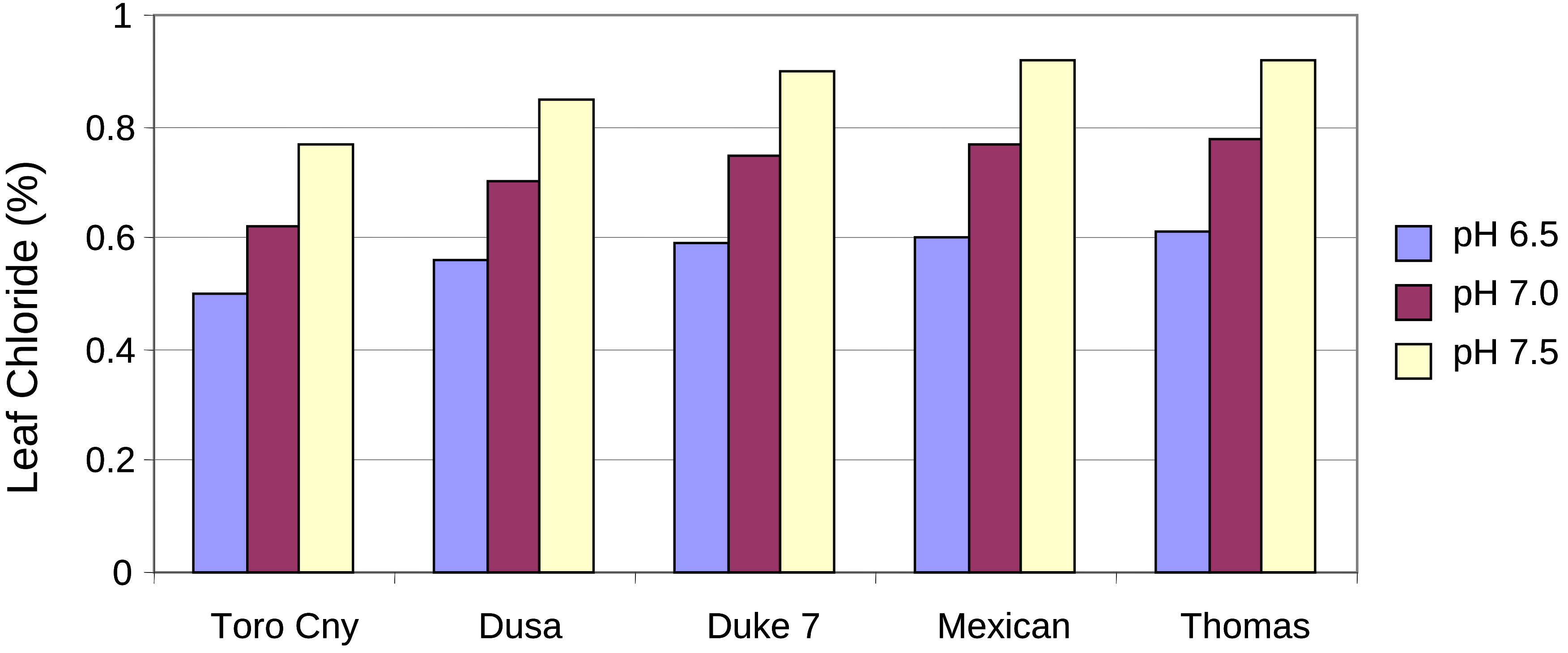
Root weight (A) and root distribution (B) in the soil profile for five avocado rootstocks grown across a 400 mile transect of the avocado production area in S. California



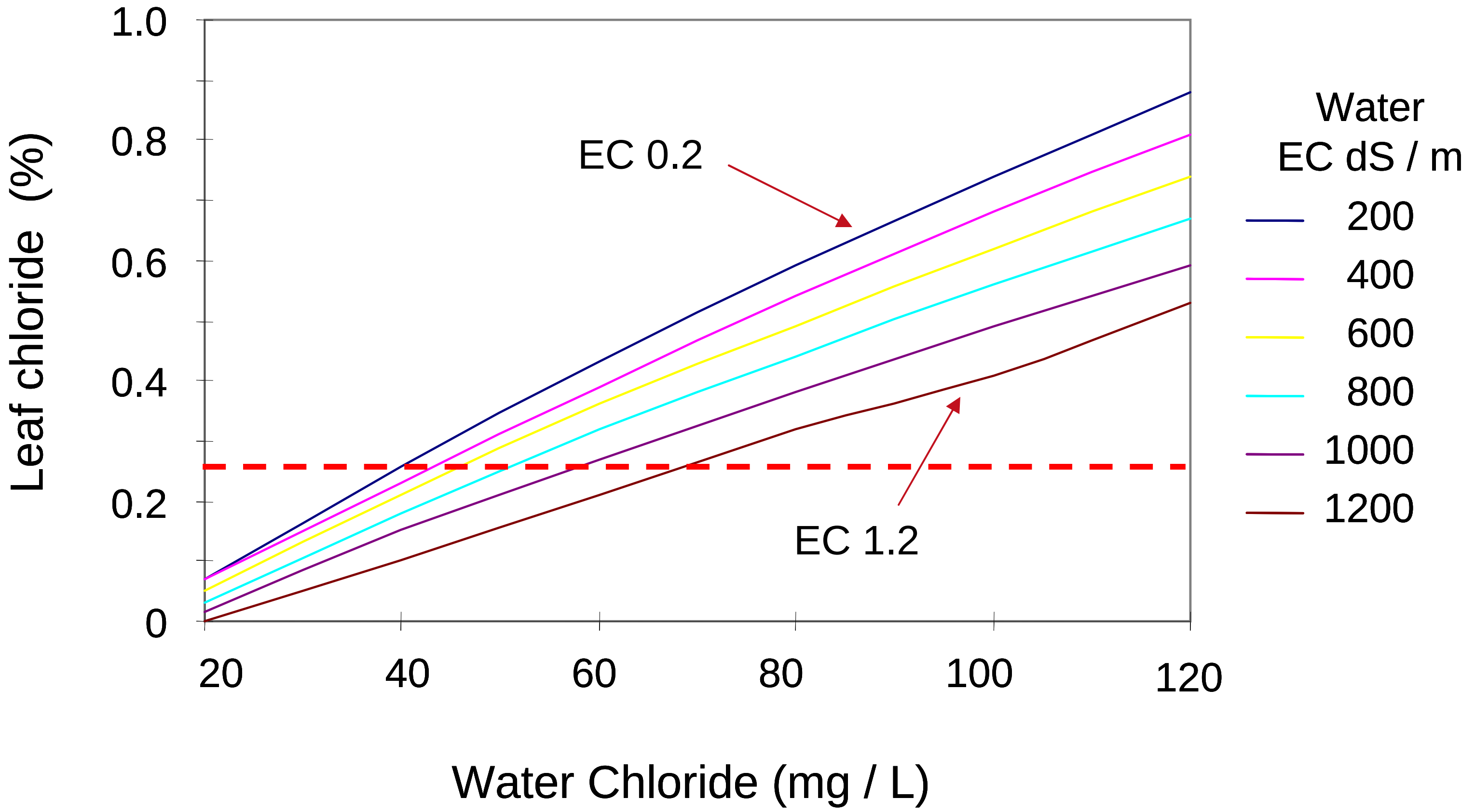
Predicted leaf chloride contents of Hass scions grafted on to five different rootstocks. The ANN model parameters are fixed for soil ECe = 4.0 dS/m; water EC 0.8 dS/m; soil pH7; Clay 30%. The dashed bar indicates 0.25% leaf chloride content at which leaf burn symptoms appear.



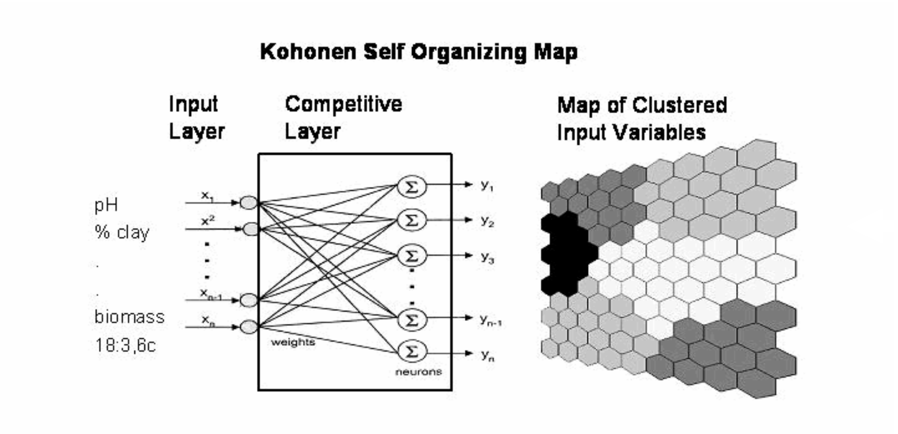
ANN predicted effect of changes in soil pH on leaf chloride content for five avocado rootstocks. Additional parameters were set under relatively harsh conditions that are associated with elevated chloride levels: soil ECe= 4.0 dS/m, soil Cl 8 mg/kg; irrigation water EC 0.8 dS/m; irrigation water chloride = 50 mg/L; soil clay content 50%.

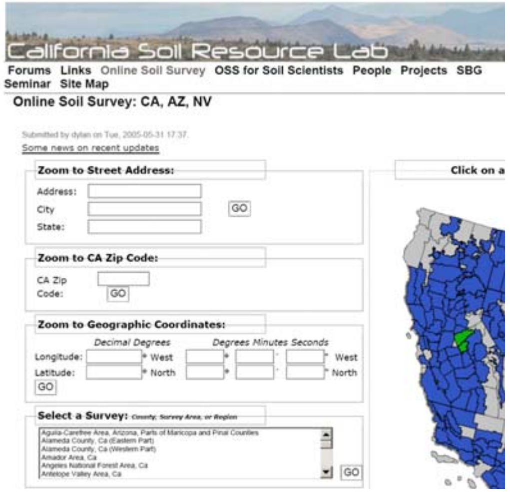


ANN model output illustrating the inverse relationship between irrigation water salinity and chloride concentrations on accumulation of chloride in leaves of Hass on Toro Canyon rootstock. Fixed model values were pH 7, 35% Clay, soil ECe 2.0, and soil Cl at 4 mg/kg



Decision Support Tools for Integration of Soil Chemical Physical Properties, Root Stock Selection, and Prediction of Economic Benefits





Soil and Climate Data

Water Quality Data, Rootstocks Used Yield Data

Questionnaire

Recommendations

Salinity Research - Benefits to the Industry

- Cost benefit analysis for irrigation water quality versus fruit yields over the full range of salinity levels that occur in water supplies used by avocado growers.

- Optimization of irrigation regimes for use of saline irrigation waters based on management of chloride versus total dissolved salts.

- Basic information on mechanisms of salinity stress and tolerance in avocado rootstocks. Improved guidance to growers for appropriate rootstock selection.

Dealing with Salinity

Proper Irrigation Management

Gypsum

Leaching

Organic Matter

Rootstock Selection

CAC Salinity Project Field Visit Time Table 2009

Tasks | **Locations and Dates**

Tasks	South Counties	Central Counties	North Counties	Moro Bay
Spring grower consults, **Data logger setups** **Spring salinity** measurements, **Sample roots** for mycorrhizae **Soil sample** for PLFA microbial community analyses	RMV Mar 2 Woodworth Mar 3 Deardorff Mar 3 Carey Mar 4	McFadden Feb 27 Steve Smith Feb 27 Mud Creek Feb 27 Lyle Snow Feb 27	Miller Mar 26 Abbot Mar 26 Van der Kar Mar 26	Staller Mar 25 Tyson Davis Mar 25
Harvest Yield Data Collection Data logger backup, site check Combined with May-June visits as feasible	RMV June 4 Woodworth June 2 Deardorff June 2 Carey June 2	McFadden May 30 Steve Smith Mud Creek Lyle Snow	Miller NA 09 Abbot Van der Kar Mar 26	Bob Staller Tyson Davis
Early Summer Soil Samples May-June 09	RMV June 5 Woodworth NA 09 Deardorff June 2 Carey June 2	McFadden May 30 Steve Smith May 30 Mud Creek May 30 Lyle Snow	Miller Abbot Van der Kar	Bob Staller Tyson Davis
Mid Summer Soil Samples (begin mid July)	RMV Woodworth Deardorff Carey	McFadden Steve Smith Mud Creek Lyle Snow	Miller Abbot Van der Kar	Bob Staller Tyson Davis
Late Summer Soil Samples (end of August)	RMV Woodworth Deardorff Carey	McFadden Steve Smith Mud Creek Lyle Snow	Miller Abbot Van der Kar	Bob Staller Tyson Davis

Typical Soil Water Analysis for Well Water San Diego County

SUBMITTED BY:	CROWLEY, DAVID	WORK REQ #:	03W003
DANR SECTION:	AGF: ENV SCI, UCR	# OF SAMPLES:	2
		DATE RECEIVED:	07/08/02
COMMODITY:	Avocado Irrigation Water	DATE REPORTED:	07/26/02
		DANR CLIENT #:	CROX1
		TURN AROUND TIME IN WORKING DAYS:	15

Sample Type: WATER   Date Sampled: 24 Oct 01 & 18 May 02; Grower/Location/Project: Stehly/San Diego/ Stehly Salinity

SAMPLE #	DESC	EC [SOP 815] mmhos/cm	pH [SOP 805]	Ca (Soluble) [SOP 835] meq/L	Mg (Soluble) [SOP 835] meq/L	Na (Soluble) [SOP 835] meq/L	Cl [SOP 825] meq/L	HCO3 [SOP 820] meq/L	CO3 [SOP 820] meq/L	B (Soluble) [SOP 835] ppm	SAR [SOP 840]	Zn (Soluble) [SOP 835] ppm	Cu (Soluble) [SOP 835] ppm
1A	24-Oct-01	2.12	8.0	10.0	7.2	6.6	8.3	3.3	0.1	0.1	2	<0.02	<0.02
1B		2.09	8.0	9.8	7.0	6.6	8.4	3.3	0.1	0.1	2	<0.02	<0.02
2A	18-May-02	3.28	8.0	14.7	14.5	9.5	13.6	3.8	<0.1	0.1	2	<0.02	<0.02
2B		3.17	8.0	14.6	14.4	9.6	13.4	3.8	<0.1	0.1	3	<0.02	<0.02
Method Detection Limit:		0.01	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1	0.02	0.02
Blank Concentration:		-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.00	0.00
Standard Ref as Tested:		0.29	6.4	0.4	0.7	1.8	0.4	2.1	-	0.3	3	50	8.6
Standard Ref Acceptable:		0.29±0.04	6.5±0.4	0.4±0.2	0.8±0.2	1.7±0.2	0.3±0.2	2.3±0.4	-	0.4±0.2	2±2	50±6	8.7±1.2
Standard Reference:		UCD 005	UCD 004	UCD 005	UCD 005	UCD 005	UCD 005	UCD 005	-	UCD 005	UCD 005	UCD 155	UCD 155

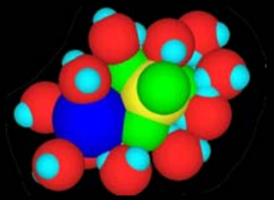
Checked and Approved: *{electronically signed by E. Sue Littlefield}*

E. Sue Littlefield, Lab Supervisor

Total Chlorides Range Measured in 2006: 8 to 13 mM, 300 – 560 ppm

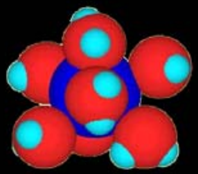
(1 meq Cl x 35 = ppm)

Gypsum Remediation of Soil



Calcium Sulfate
Molecule

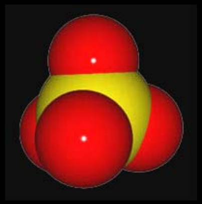
+2



Calcium

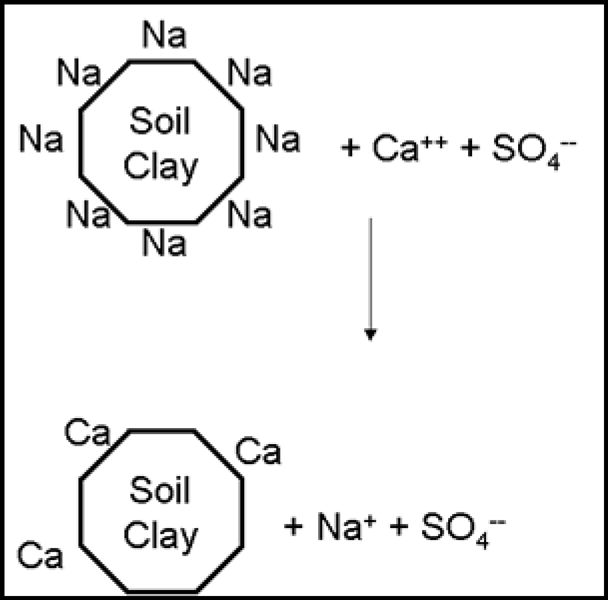
+

-2



Sulfate

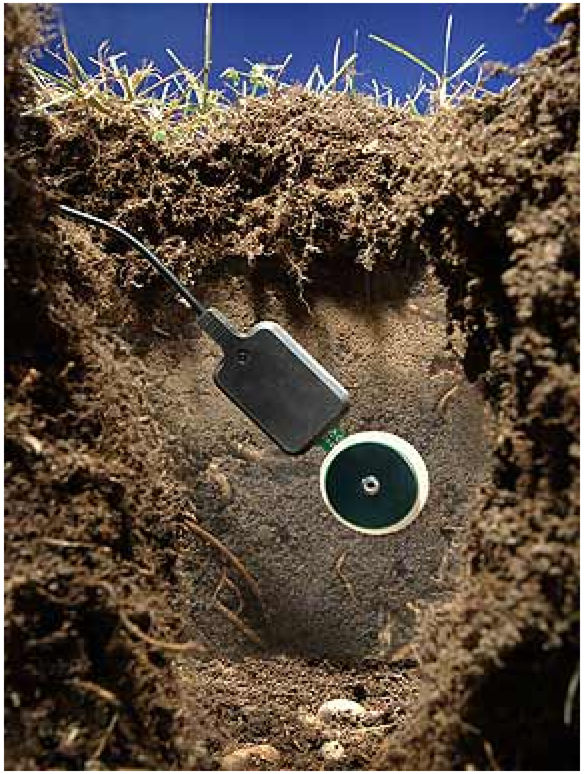
Gypsum -
Calcium Sulfate

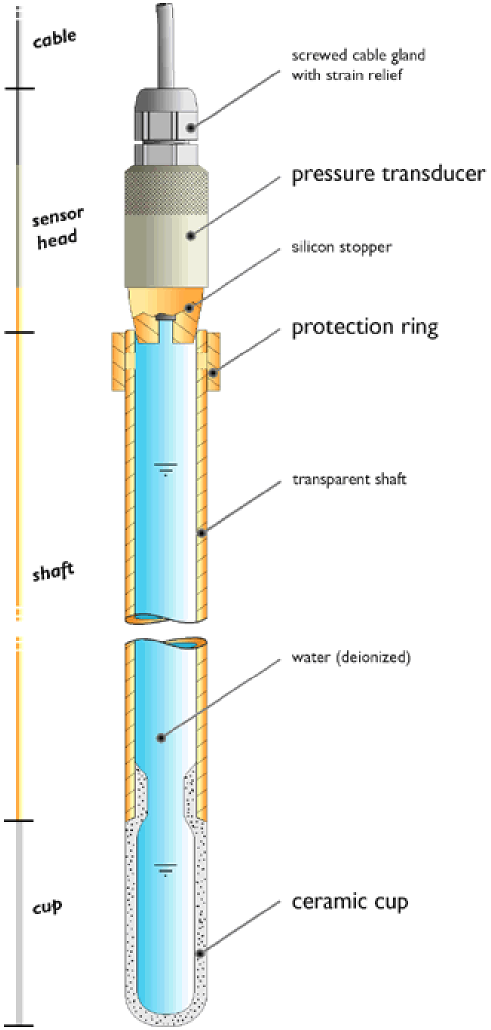


Effect of Pore Size Distribution on Soil Water and Air

	Residual	Storage	Transmission
	Pores < 0.5 uM	Pores 0.5 – 50 uM	Pores 0.5 – 50 uM
	Water not available	Water available	Gravity drained
	Always filled with water	Water or gas filled	Always filled with air
Sandy soil:	**5%**	**15%**	**20%**
Clay soil:	**25%**	**30%**	**5%**

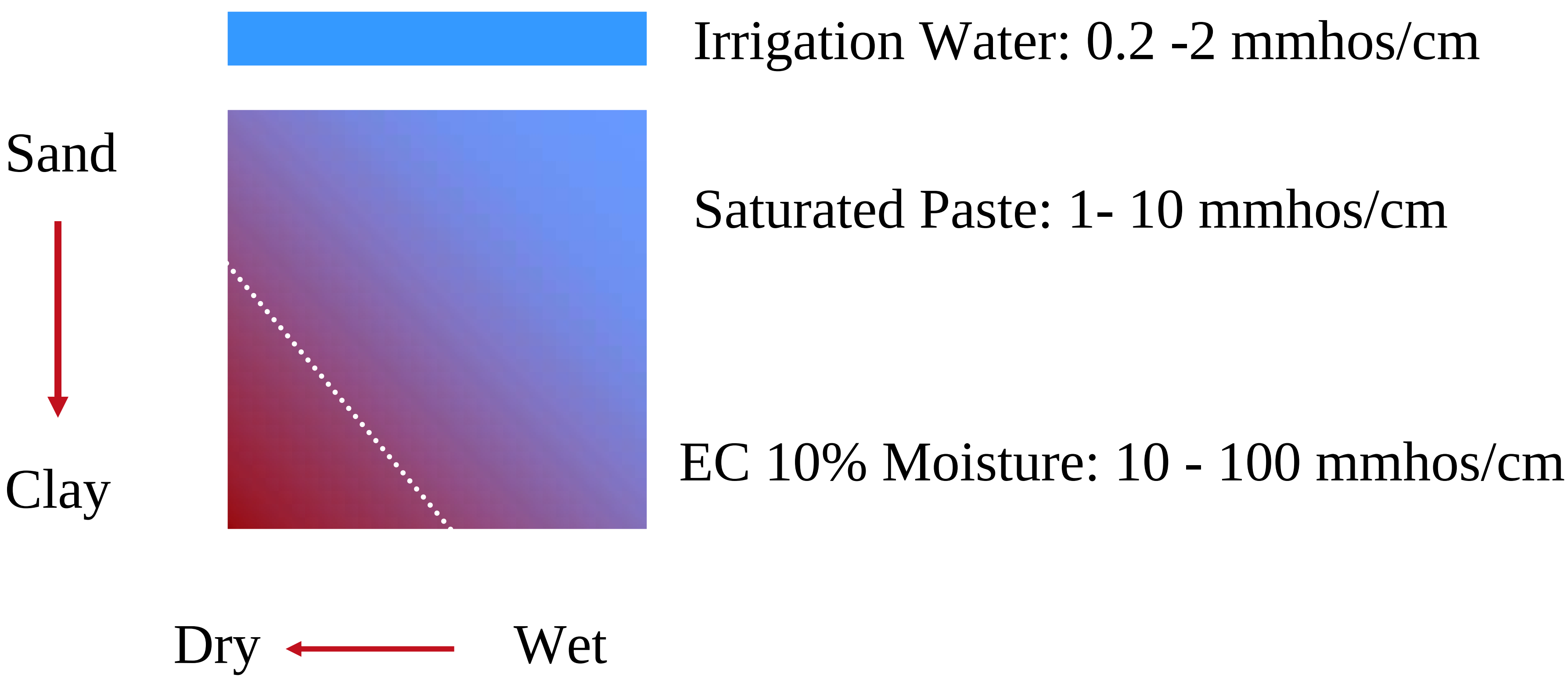
Tensiometers





Salinity of Soil Solution vs Irrigation Water
Effect of Soil Texture and Soil Drying

Soils accumulate salt and will be more saline than the irrigation water.
The salt further concentrates as the soil dries out.



TDS/Conductivity/Salinity Pen

If using irrigation water to prepare extract.

Collect Soil Cores

0-6”, 6-12”, 12-18”

Prepare 2:1 Water:Soil Extracts

Irrigation Water

Measure EC of irrigation water and

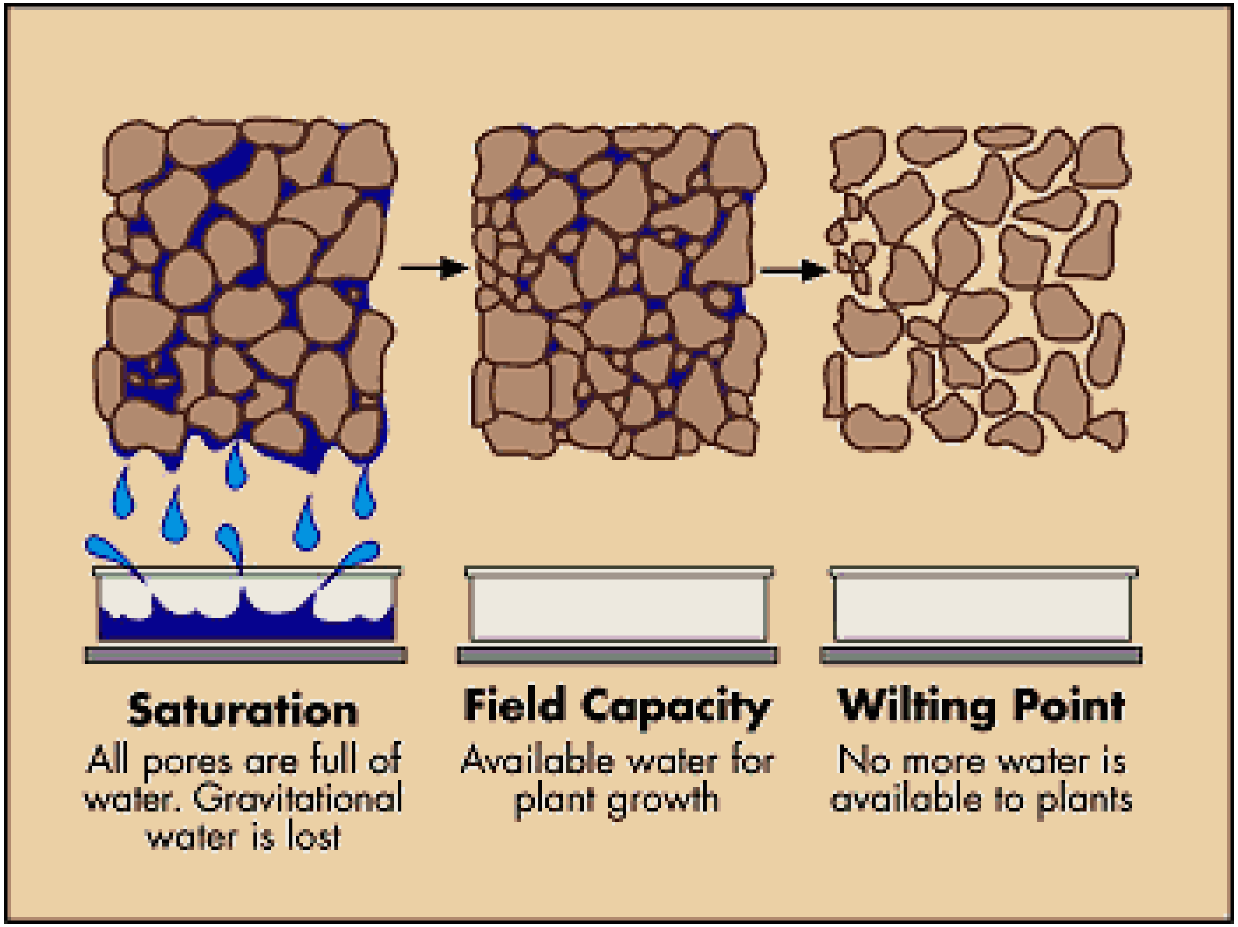
EC of Irrigation water + soil (2:1)

Calculation: (EC of irrigation water + soil)

<u>- EC of irrigation water)</u>

If difference > 0.35 dS/m, then time to leach.

Water retention in soils



Are there interactive effects of salinity TDS and Cl?

Plant responses

Dissolved Solids

Chloride

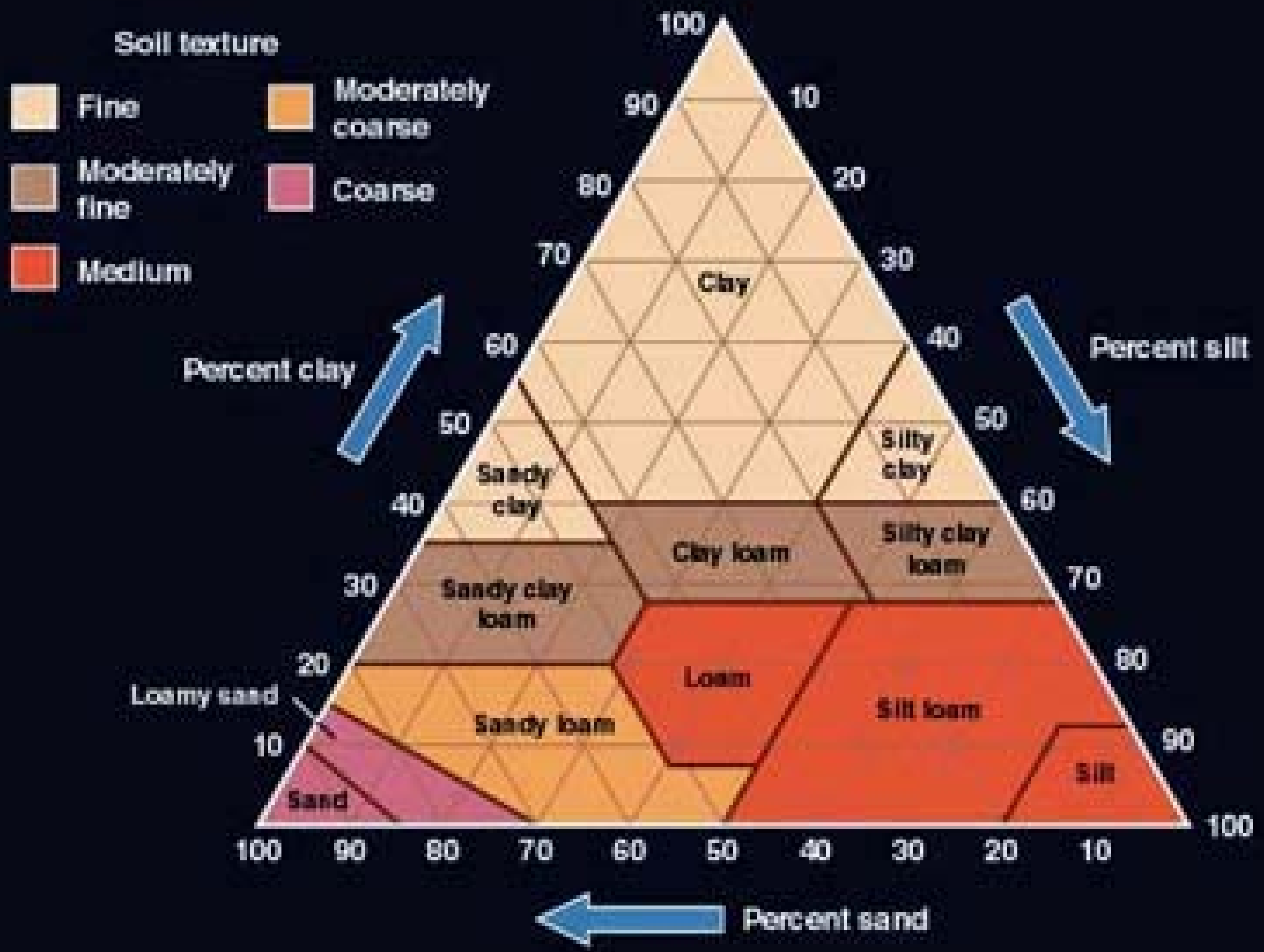
EC 0.57 ->Threshold for Yield Decline
65% yield reduction per $dS\ m^{-1}$ increase

Chloride- Threshold Unknown
15 mM -> 40% decline in root growth

Interactions?

Responses of Avocado Rootstocks to High Salinity Irrigation Water

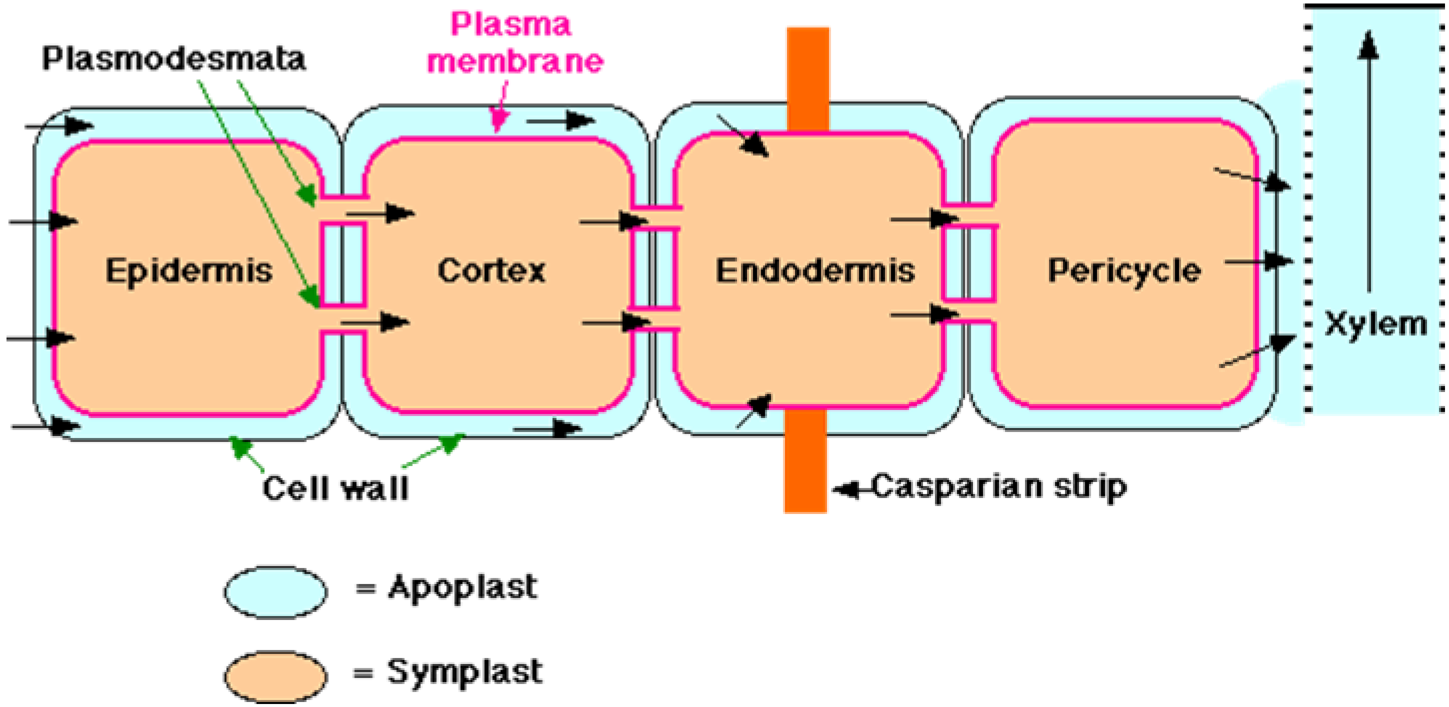
Soil Texture: % Sand, Silt, Clay



The Role of Soil Texture (Sand, Silt, Clay)

Sands – do not bind sodium,
little or no effect on soil structure
good water infiltration
easily leached

Clays – bind sodium, disperses particles
strong effect on soil structure
poor water infiltration
difficult to leach salt



Plasmodesmata
Plasma membrane
Epidermis
Cortex
Endodermis
Pericycle
Xylem
Cell wall
Casparian strip
= Apoplast
= Symplast

Benefits to the Industry

- Cost benefit analysis for irrigation water quality versus fruit yields over the range of salinity levels that occur in water supplies currently used by avocado growers.

- Optimization of irrigation regimes for use of saline irrigation waters based on management of chloride versus total dissolved salts.

- Basic information on mechanisms of salinity stress and tolerance in avocado rootstocks.

- Recommendations for rootstock selections based on field performance.

- Improved guidance to growers for salinity management.

- Development of an artificial neural network ANN model, that can be deployed on an internet location for use by growers to examine the effects of salinity, chloride, soil properties, rootstocks and management practices on root growth and yields of avocado in California.

Deficiency

- Potassium
  - Leaf tip and marginal burn, starting on mature leaves
  - Small fruit, shriveled seeds
  - Slow growth
  - Thin twigs, dieback
  - Confused with chloride tip-burn which is much more common

Diagnosis and Improvement of

Saline and Alkali Soils

United States Salinity Laboratory Staff

BOX 9.5 LEACHING REQUIREMENT *LR*

A farmer should know how much leaching water is required to prevent the buildup of salts in a soil or, if the salts are already high, to reduce their levels in the soil. The concept of *leaching requirement LR* has been developed to help farmers make this assessment.

The *LR* is the irrigation water needed (in excess of that required to saturate the soil) to sufficiently leach the soil so as to assure a proper salt balance for the crop being grown. It is approximated by the ratio of the electrical conductivities (ECs) of the incoming irrigation water EC_w and of the outgoing drainage water EC_{dw} that has an acceptable EC level for the crop being grown.

$$LR = \frac{EC_w}{EC_{dw}}$$

As an example, consider the situation where the EC of the irrigation water EC_w is 2.5 dS/m and that of the acceptable draining soil solution is 5.5 dS/m. Then,

$$LR = \frac{2.5\ \text{dS/m}}{5.5\ \text{dS/m}} = 0.45$$

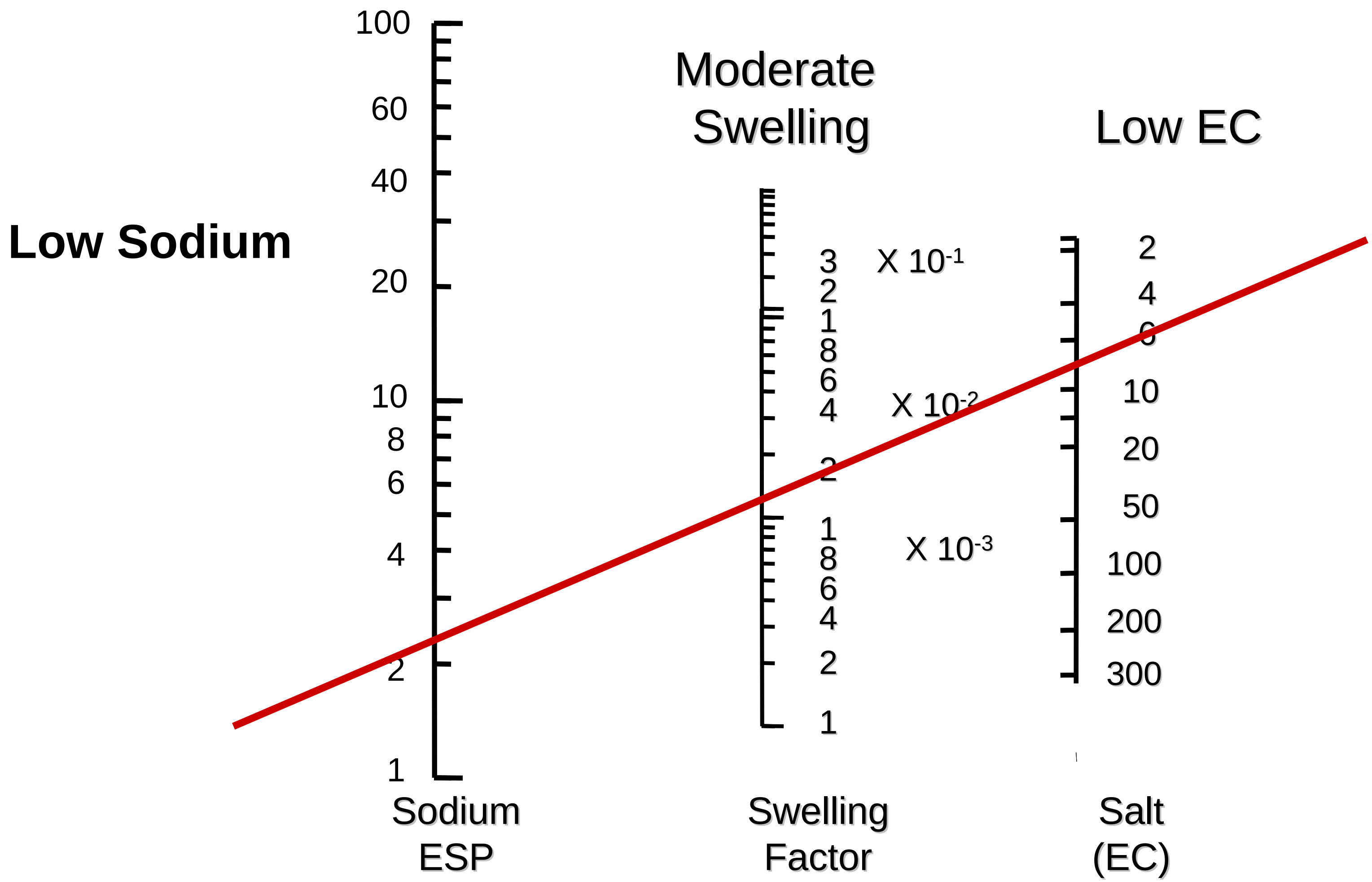
If this ratio (0.45) is multiplied by the amount of water needed to completely saturate the soil—perhaps 8 cm of water—the water to be leached can be calculated as follows:

$$8\ \text{cm} \times 0.45 = 3.6\ \text{cm water}$$

This is the minimum amount of water that must be leached through a water-saturated soil to maintain proper salt balance. In some cases, additional leaching may be needed to reduce the excess concentration of specific elements such as boron.

The modern means of measuring bulk soil conductivity EC_a using the four-electrode probe or remote-sensing electromagnetic induction devices (see Section 9.15) can be used to readily monitor soil salinity changes resulting from leaching practices.

Soil Swelling Factor:
Sodium Content (SAR) vs Salt Content (EC)



Ezekiel 47:11

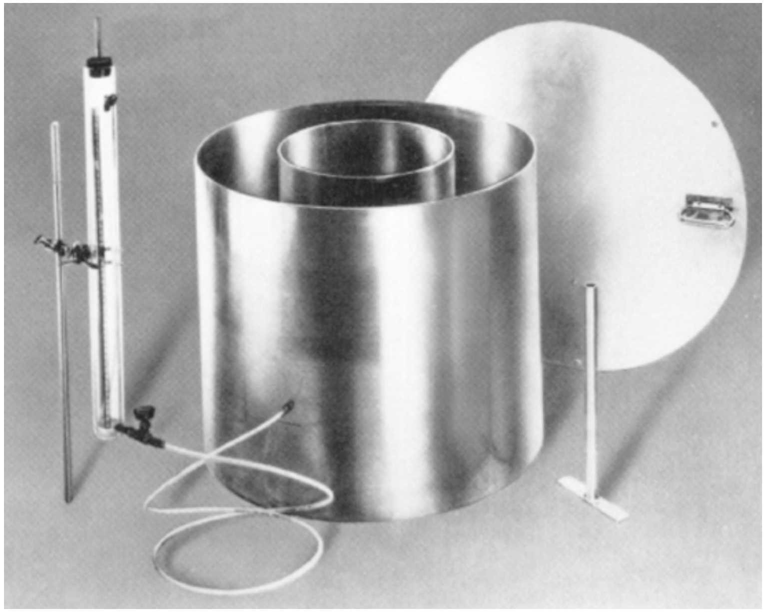
"But the miry places thereof and the marshes thereof shall not be healed; they shall be given to SALT."

www.ars.usda.gov/.../ sep05/saline0905.htm

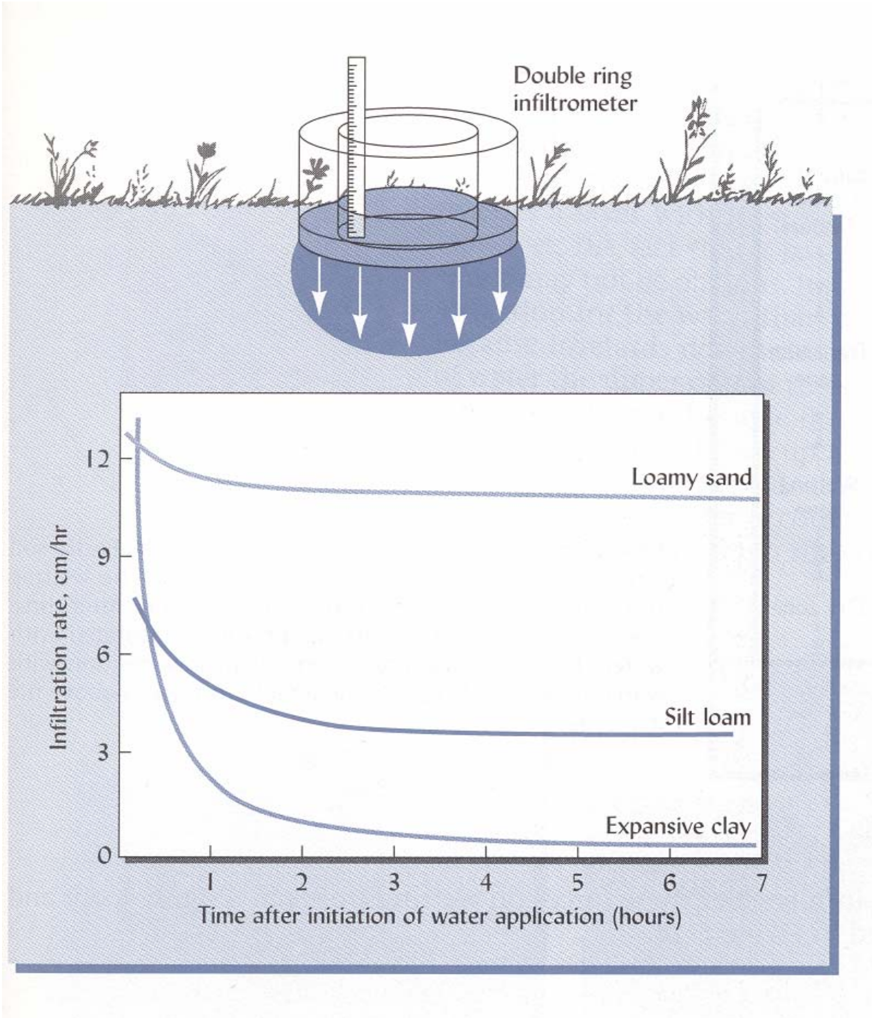
Hydraulic Conductivity of Hoytville Soil

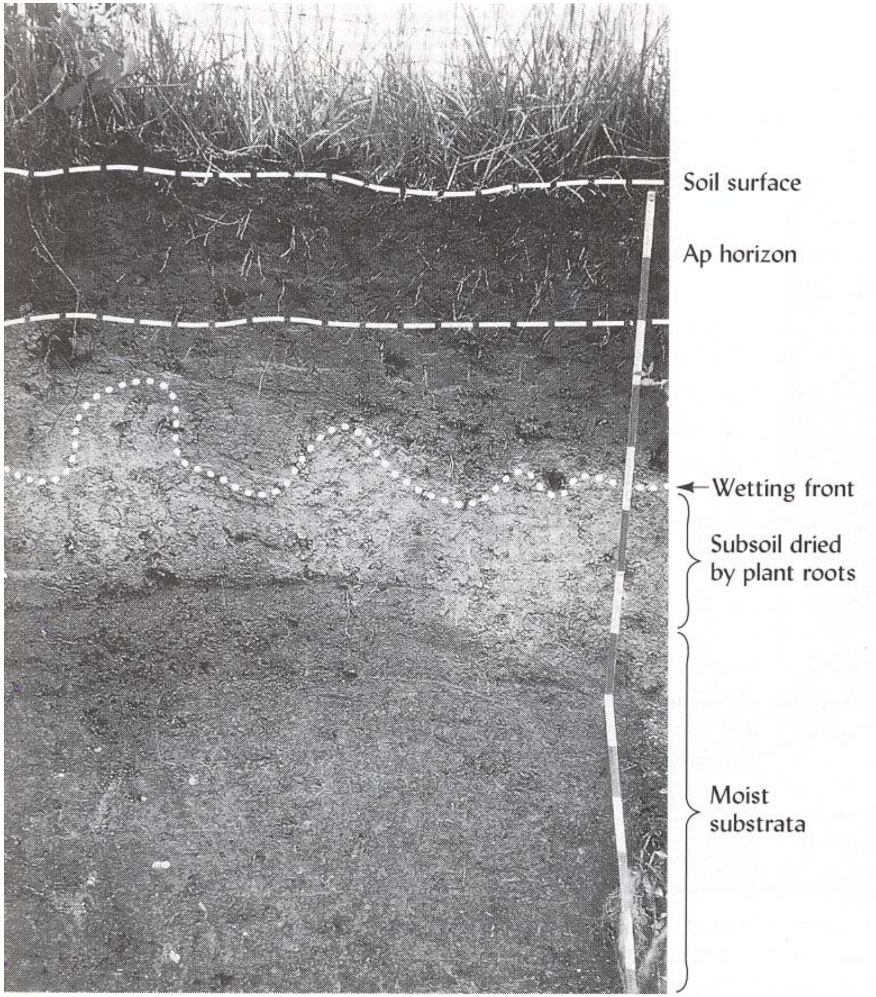
Depth	**Hydraulic conductivity**	
inches	**Natural Soil**	**Farmed Soil**
	inches / day	
0 - 8	4.8 – 48	3.8
8 - 20	4.8 - 14.4	1.4
20 - 52	4.8 - 14.4	7.0
52 - 60	1.4 - 4.8	7.0

Double ring infiltrometer for measuring soil water permeability

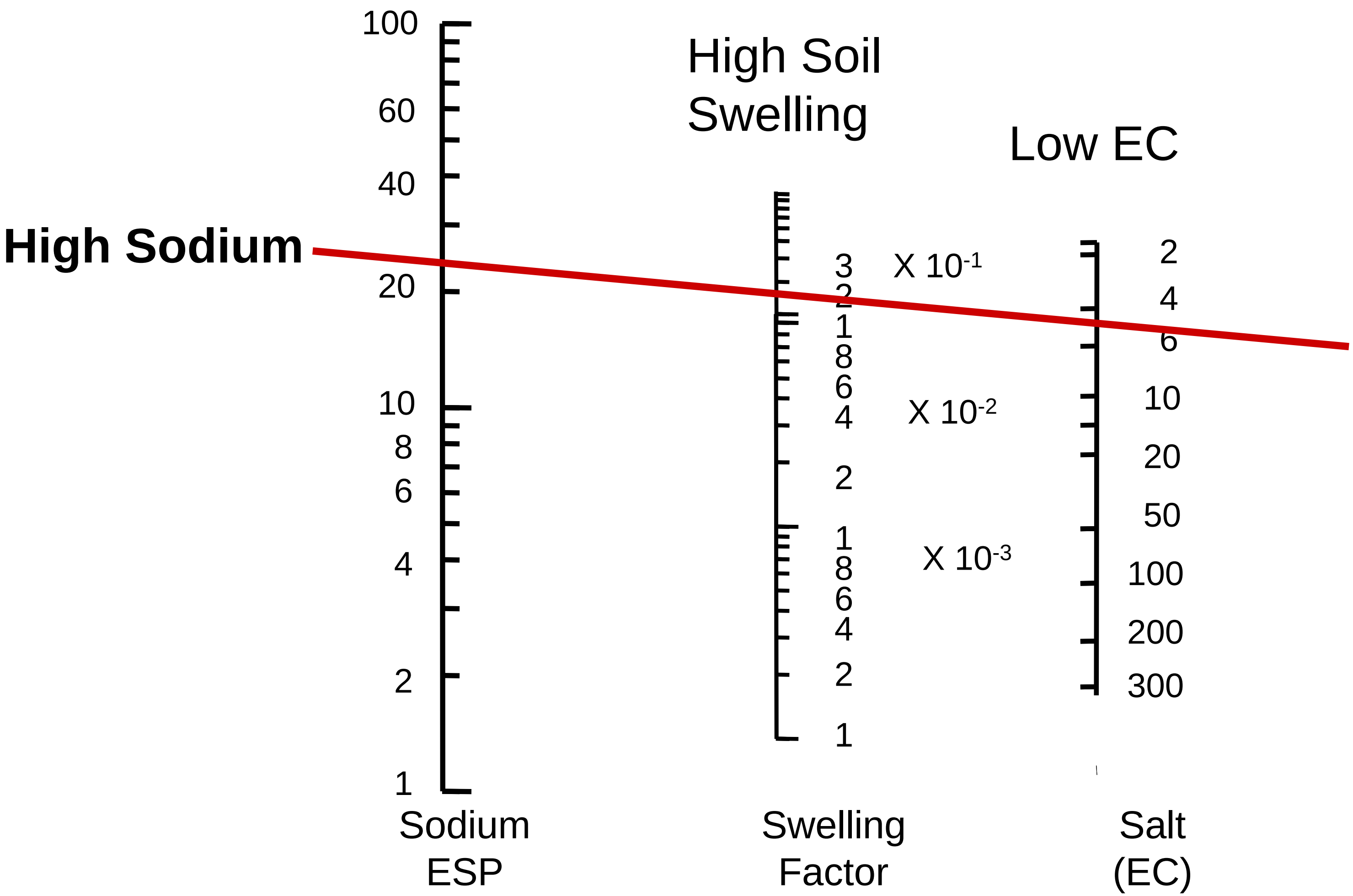


Hydraulic Conductivity in Different Soils

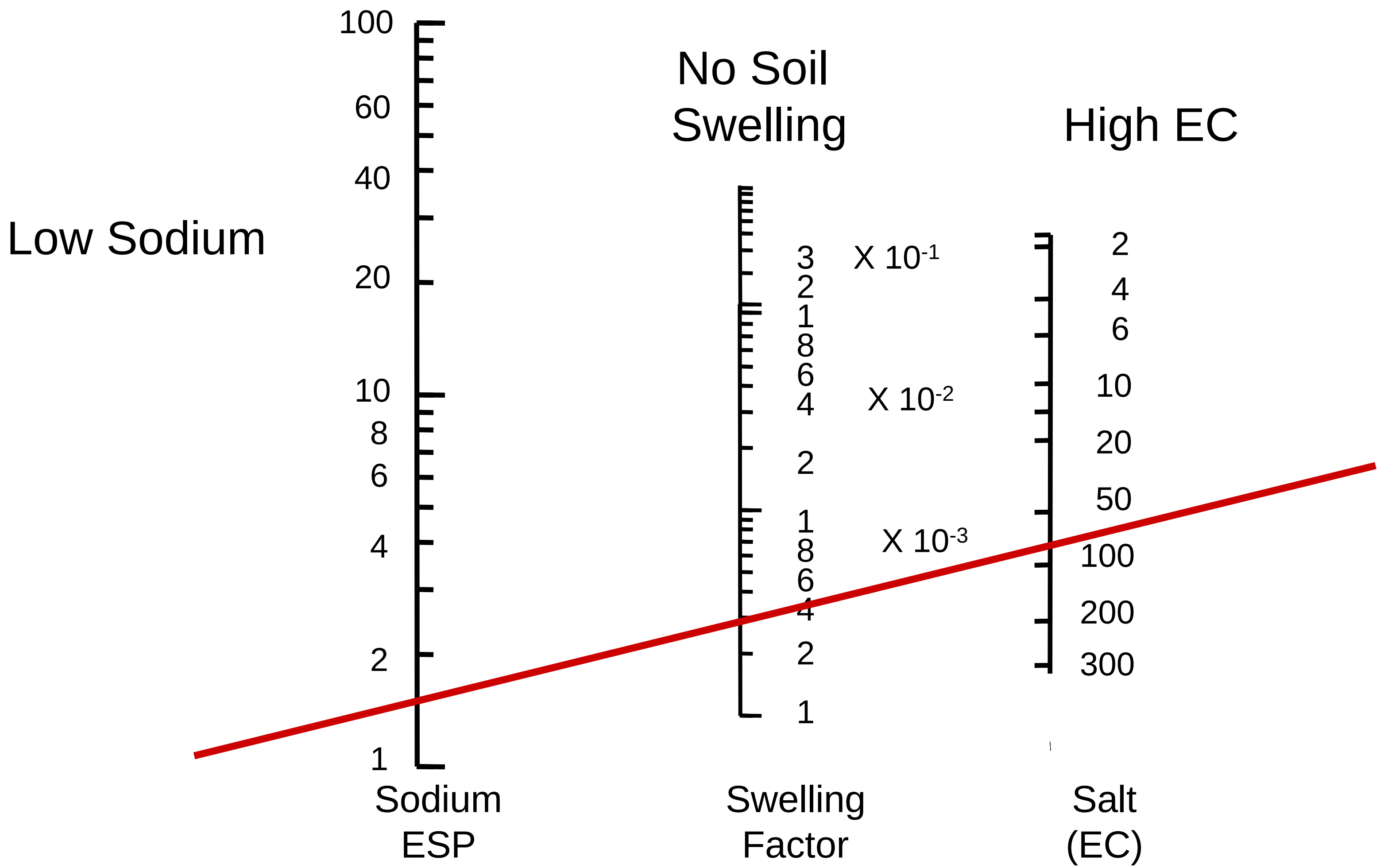




Soil Swelling Factor:
Sodium Content (SAR) vs Salt Content (EC)



Soil Swelling Factor:
Sodium Content (SAR) vs Salt Content (EC)



Recent Research Has Identified Avocado Rootstocks that Vary in Salinity Tolerance

Rio Frio

Duke 7

VC 801

VC 218

Steddom

PP 14 Uzi

VC 207

Spencer

VC 44

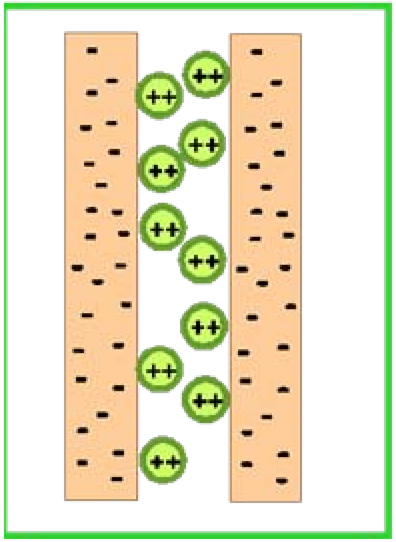
Importance of Soil Texture for Water Holding

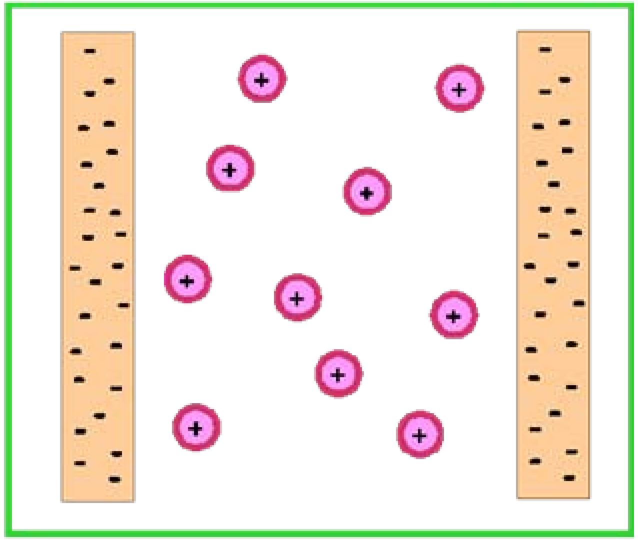
Texture	Available Water Storage Capacity: Short Growing Season Crops (in./4 ft.)	Available Water Storage Capacity: Long Growing Season Crops (in./5ft.)
Coarse Sand and Gravel	2.0	2.5
Sand	3.2	4.0
Loamy Sand	4.4	5.5
Sandy Loam	6.0	7.5
Fine Sandy Loam	7.6	9.5
Loam and Silt Loam	9.6	12.0
Clay Loam	8.4	10.5
Silty Clay and Clay	7.6	9.5

Salinity: Sodium and Chloride

Good Salts: Calcium, Magnesium
Hold soil particles together

Problem Salts: Sodium – soil dispersion
Chloride - toxicity



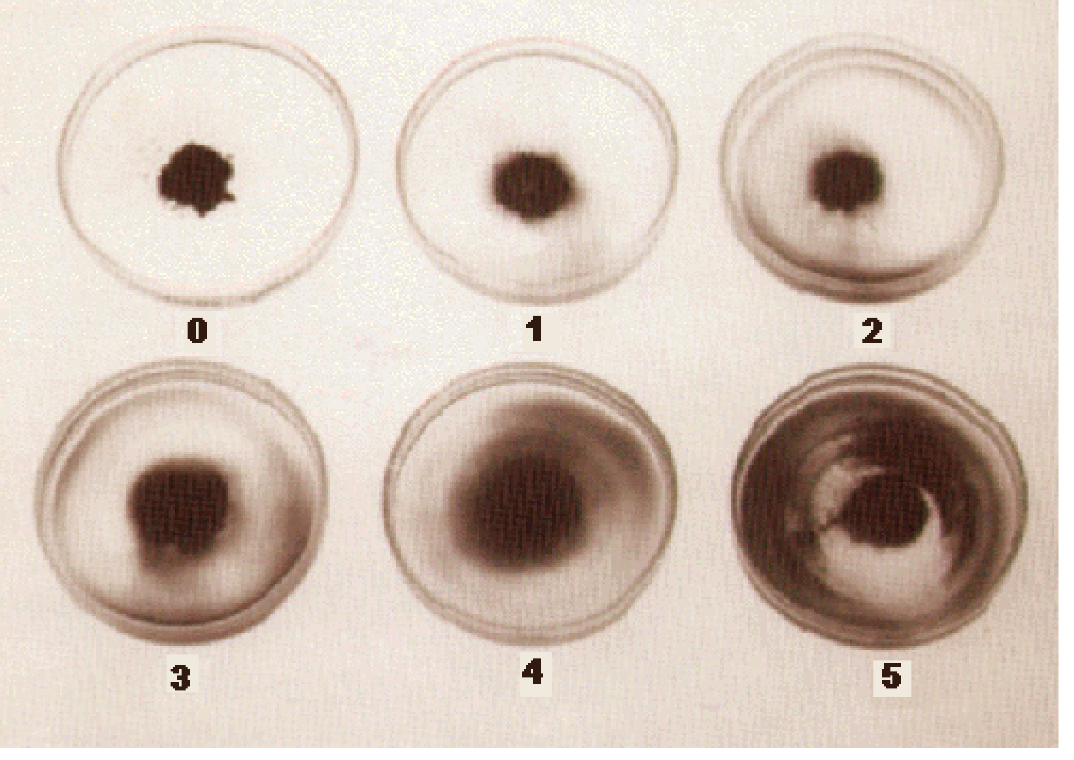


Calcium and magnesium help soil particles stick together; Sodium causes the soil particles to disperse.

Low Sodium High Sodium

High Ca++, Mg++

Low Ca++, Mg++



Poor water infiltration leads to soil ponding: poor leaching, salt accumulation, low soil oxygen, root death from anoxia, and increased Phytophthora root rot.

Consequences of Soil Dispersion

Poor Drainage:

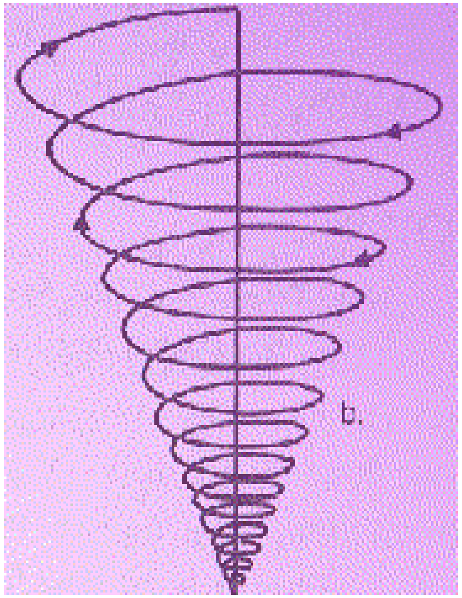
- Less infiltration of water
- Increased water runoff
- Less efficient leaching of salt

Loss of Soil Structure

- Loss of soil pore space
- Decreased oxygen
- Increased soil erosion

Plant Effects

- High soil bulk density
- Decreased root growth
- Anoxia and root death



Loss of soil structure leads to a spiral effect that results in decreased soil quality, poor plant growth, root disease, low yields.

Measurement of Salinity Effects on Water Infiltration:

The Double Ring Infiltrometer

Table 2. Steady infiltration rates for general soil texture groups in very deeply wetted soil (Hillel, 1982).

Soil type	Steady infiltration rate (inches per hour)
Sands	> 0.8
Sandy and silty soils	0.4 - 0.8
Loams	0.2 - 0.4
Clayey soils	0.04 - 0.2
Sodic clayey soils	< 0.04

How can we determine whether salinity is affecting soil quality?

Sodium Absorption Ratio (SAR)

$$\sqrt{\frac{Na^{+}}{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Table 3. Combined effect of electrical conductivity (ECw) of irrigation water and sodium adsorption ratio (SAR) on the likelihood of water infiltration (permeability) problems

Sodium adsorbtion ration (SAR) of irrigation or soil	Water infiltration problem	
	Unlikely when ECw (dS/m) is more than	Likely when ECw (dS/m) is less than
0–3	0.6	0.3
3–6	1.0	0.4
6–12	2.0	0.5
12–20	3.0	1.0
20–40	5.0	2.0

Relationship Between Salinity and Sodicity and Water Infiltration Rates