Water Quality and Avocado Production

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Would you put this on your orchard?

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

How Much Salt is in Your Water?

1 Acre Foot = 1,233,000 Liters

X

TDS = 500 mg / Liter

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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

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66 - 124 kg Na

87 - 118 kg Cl

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153 - 242 kg NaCl

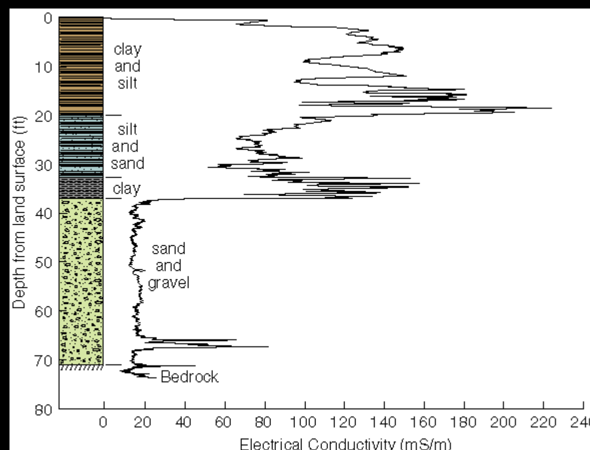
How Much Salt is in Your Water?

4 Acre Feet:

612 - 968 kg NaCl

2464 kg total dissolved salt

Measuring Salinity: Electrical Conductivity



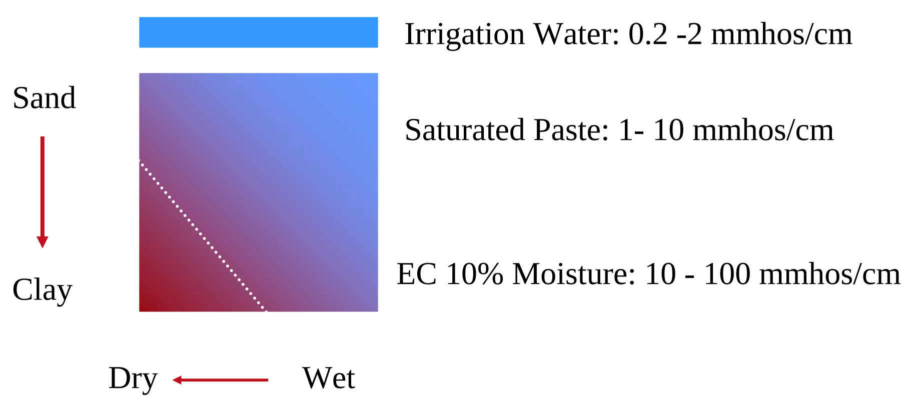
Units for measuring salinity, and conversion factors.			
Conversion factors relating total dissolved salts or pure NaCl to an electrical conductivity (EC) of 1 dS/m (1 deciSiemen/metre) are given, along with equivalent units of various types, old and new. The conversion of EC of 1 dS/m to total dissovled 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

Suitability of Water for Irrigation

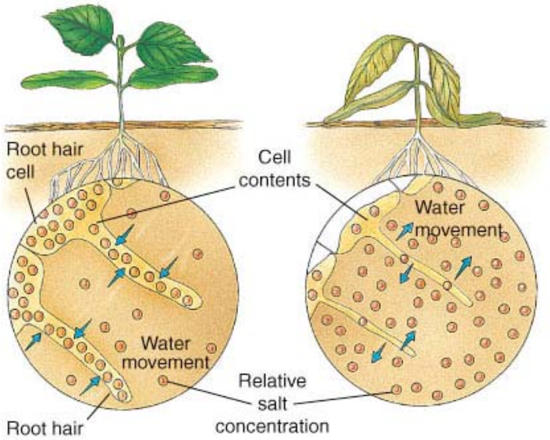
Quality	Electrical Conductivity (millimhos/cm)	Total Salts (ppm)	Sodium (% of total salts)	SAR	pH
Excellent	0.25	175	20	3	6.5
Good	0.25-0.75	175-525	20-40	3-5	6.5-6.8
Permissible	0.74-2.0	525-1400	40-60	5-10	6.8-7.0
Doubtful	2.0-3.0	1400-2100	60-80	10-15	7.0-8.0
Unsuitable	>3.0	>2100	>80	>15	>8.0

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.



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



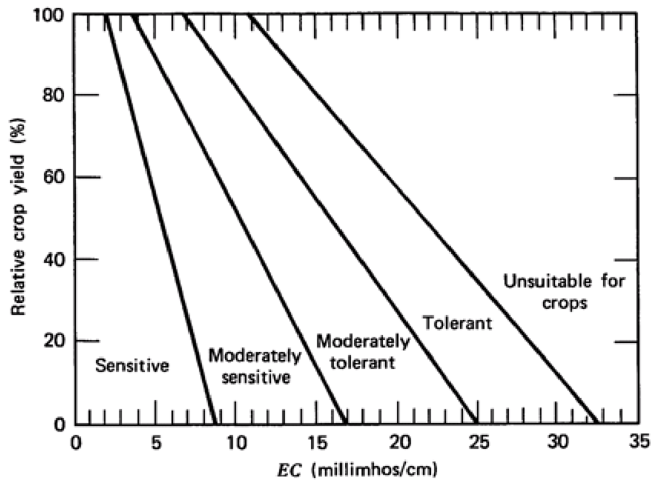
For avocado, this occurs at EC = 4 dS/m

Water enters the plant by osmosis

Salt in the soil sucks water out from the plant roots

Benjamin Cummings: Basic Plant Physiology

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.



USDA Salinity Handbook

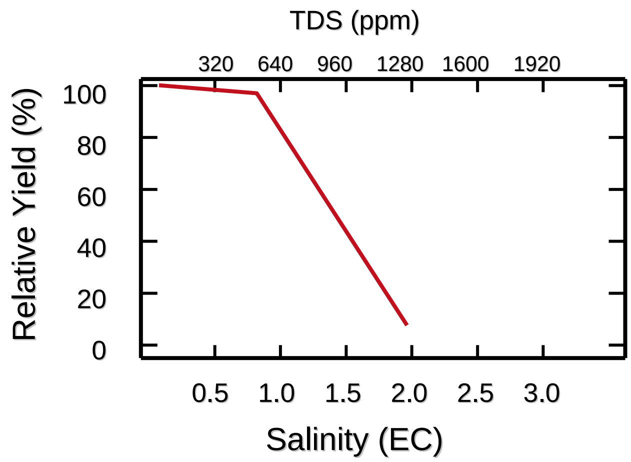
Table 6. Effect of Root Zone Salinity on Crop Productivity of Selected Crops (Carter, 1981).

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



Irrigation Water Salinity

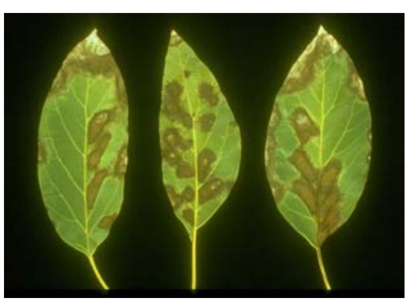
Salts in irrigation water include dissolved minerals:

Cations	Anions
Calcium Ca^{++}	Sulfate SO_4^{2-}
Magnesium Mg^{++}	Carbonate CO_3^{2-}
Sodium Na^{+}	Chlorides 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

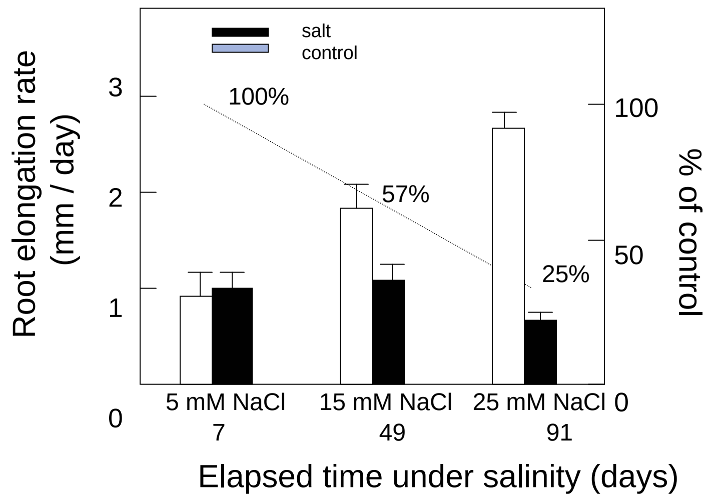


Chloride 0.58%
Sodium 0.35%

Chloride 0.61%

Kadman (Avocadosource.com)

Effects of Chloride Toxicity on Root Growth

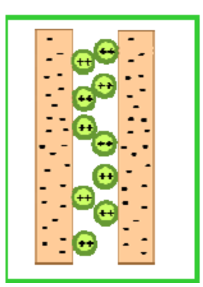


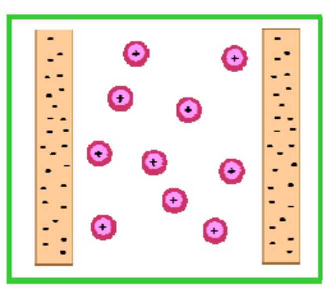
Berstein (Avocadosource.com)

Salinity: Sodium and Chloride

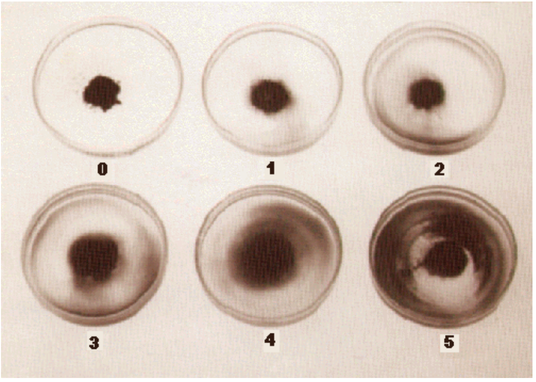
Good Salts: Calcium, Magnesium
Hold soil particles together

Problem Salts: Sodium – soil dispersion
Chloride - toxicity





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

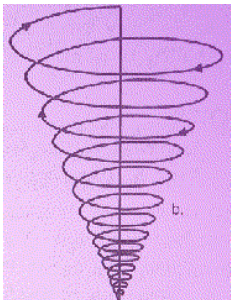


Consequences of Soil Dispersion

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

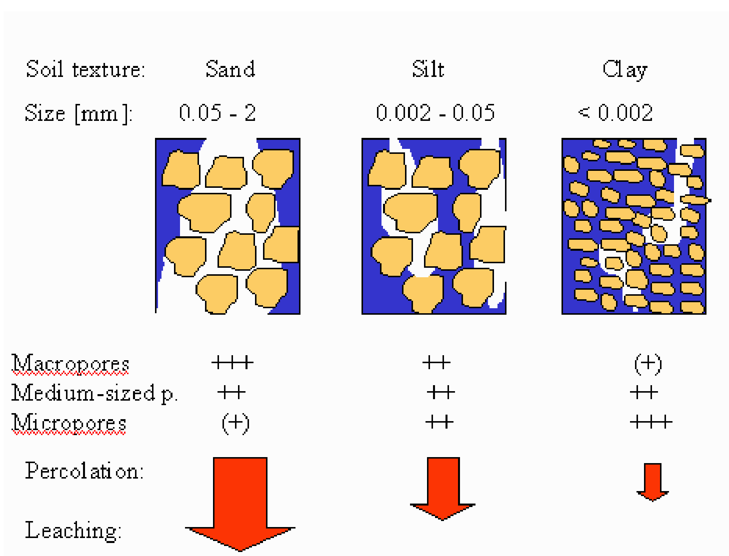
Plant Effects
- High soil bulk density
- Decreased root growth
- Anoxia and root death



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

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

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



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

USDA Soil Quality Test Kit

How can we determine whether salinity is affecting soil quality?

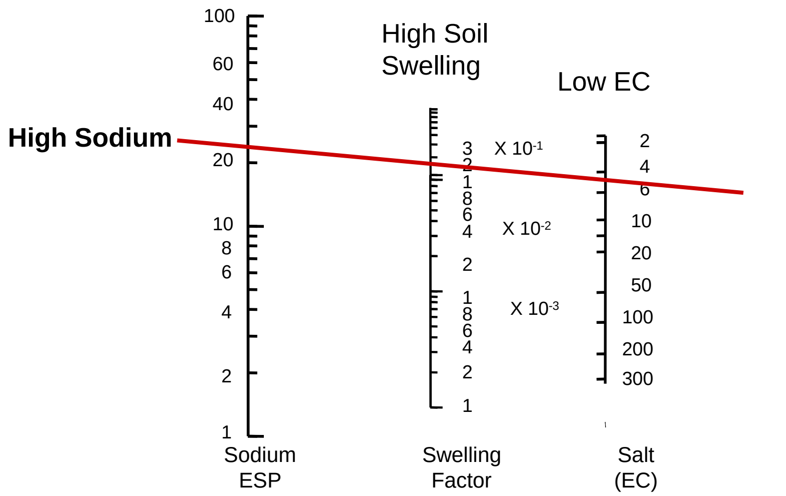
Sodium Absorption Ratio (SAR)

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

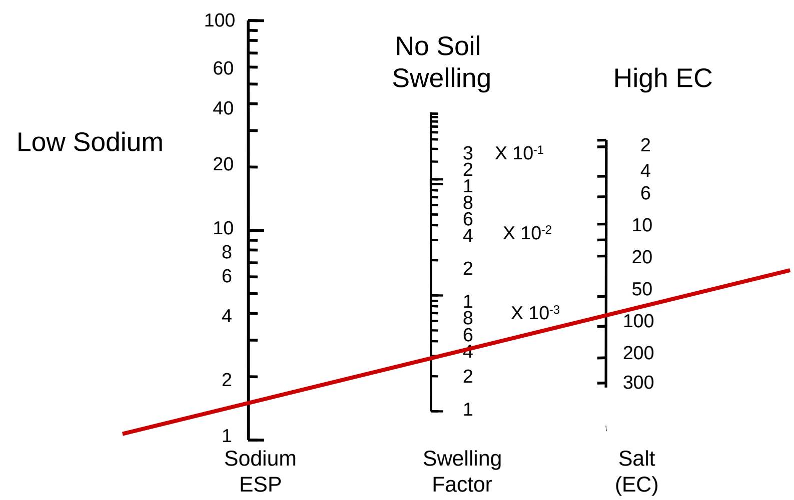
Table 3. Combined effect of electrical conductivity (ECw) of irrigation water and sodium adsorption ratio (SAR) on the likelihood of water infiltration (permeability) problems

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

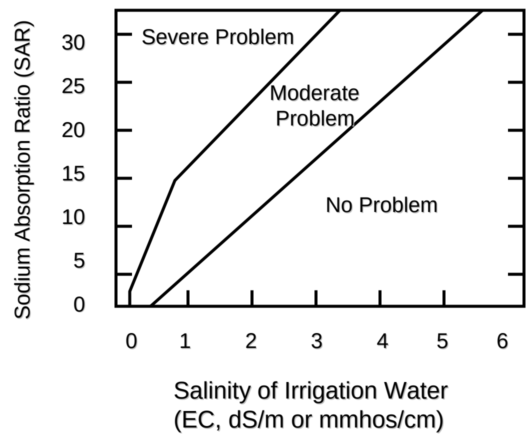
Soil Swelling Factor:
Sodium Content (SAR) vs Salt Content (EC)



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



Relationship Between Salinity and Sodicity and Water Infiltration Rates



Dealing with Salinity

Proper Irrigation Management

Gypsum

Leaching

Organic Matter

Rootstock Selection

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%**

www.plantstress.com/articles/waterlogging

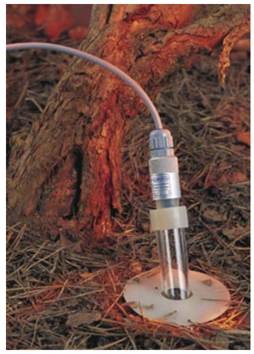
Measurement of Soil Water Potential

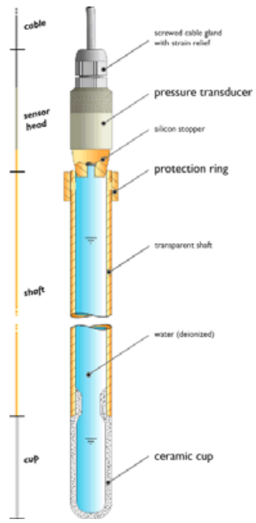
Time Domain Reflectometery (TDR)

Absorbent Blocks

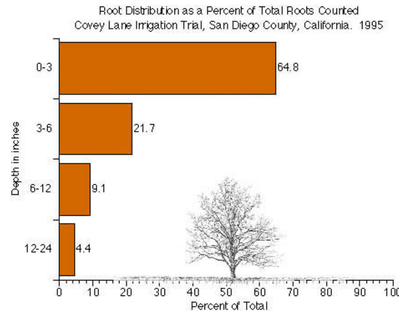
Tensionmeter

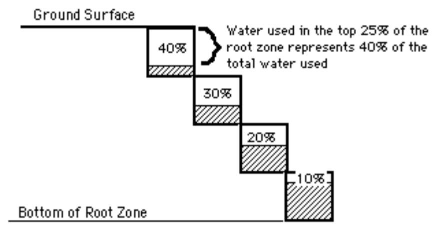
Tensiometers





Root Depth Distribution for Avocado

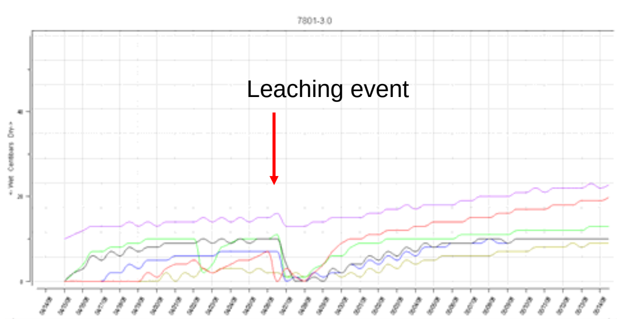


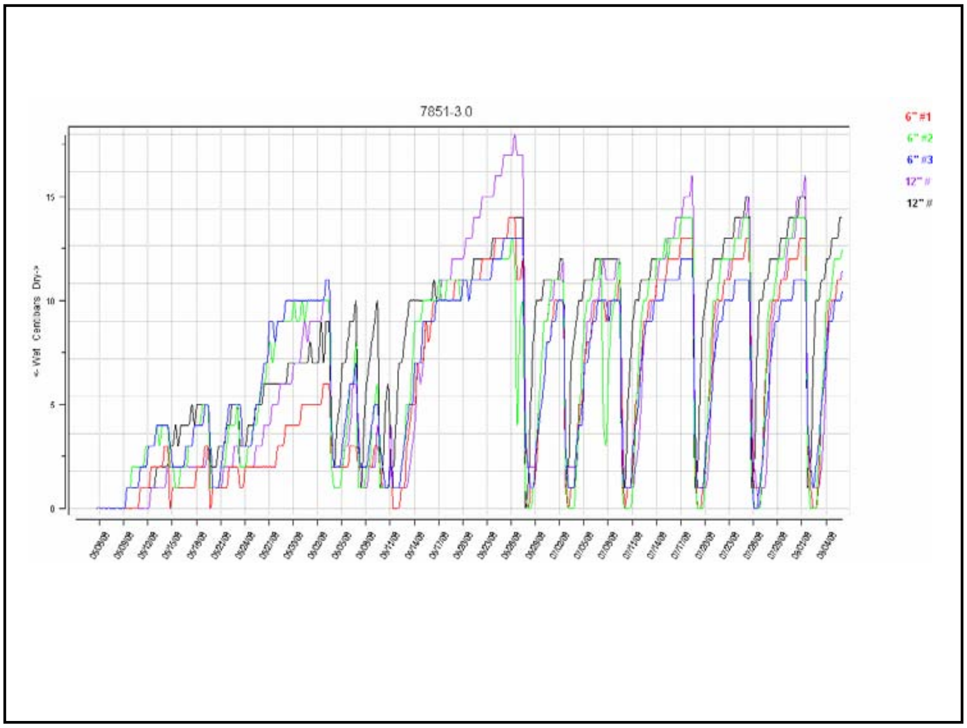


http://ucavo.ucr.edu/AvocadoWebSite%20folder/AvocadoWebSite/Phenology/RootDist.html

Water Mark Probes

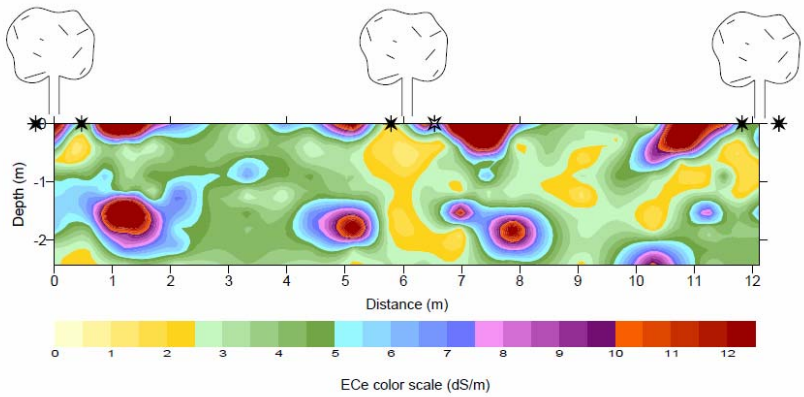
1. Soil temperature
2. Tree 1 6 inch
3. Tree 2 6 inch
4. Tree 3 6 inch
5. Tree 1 12 inch
6. Tree 2 12 inch
7. Tree 3 12 inch
8. Tree 1 24 inch




7851-3.0
<- Wet Centibars Dry->
0
5
10
15
6" #1
6" #2
6" #3
12" #
12" #

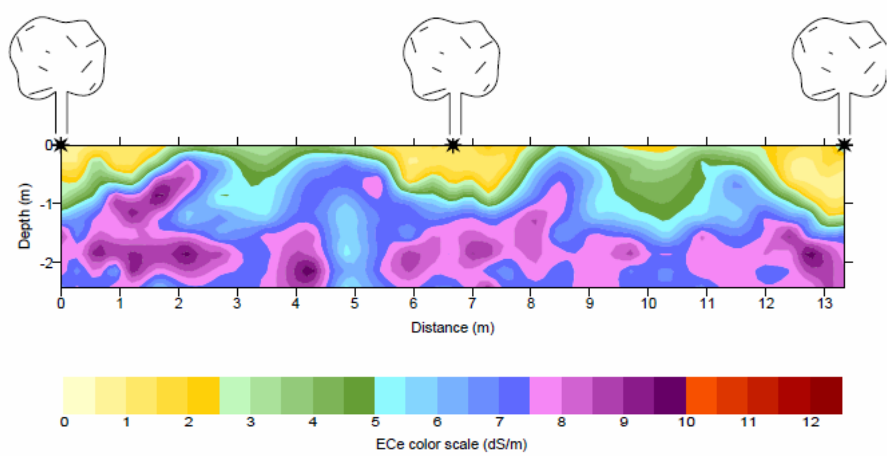

Soil Leaching: Pushing Salt Down

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

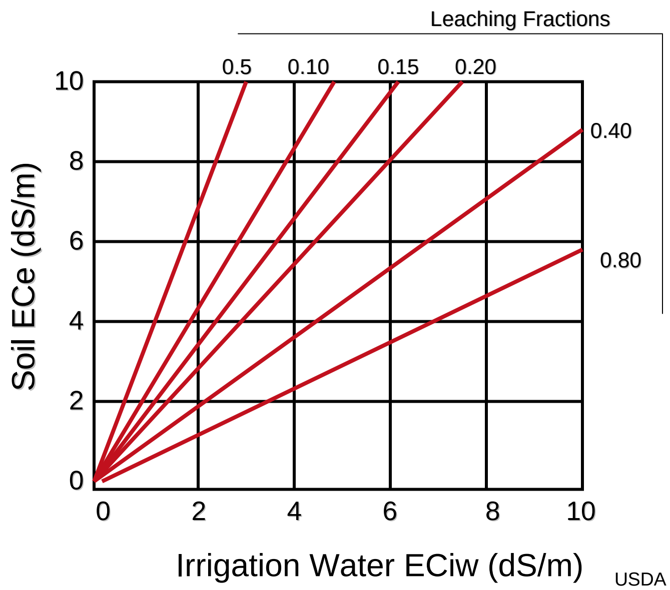
Salt Accumulation in Tree Crop Orchards Using Micro-Spray Irrigation



CDWR 2003

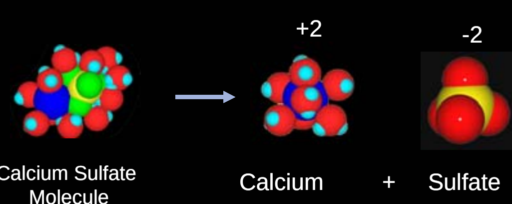
Soil Salinity Accumulation in Orchards with Drip and Micro-spray Irrigation in Arid Areas of California
http://www.itrc.org/reports/salinity/treecropsalinity.pdf ITRC Report No. R 03-005

Leaching Fraction

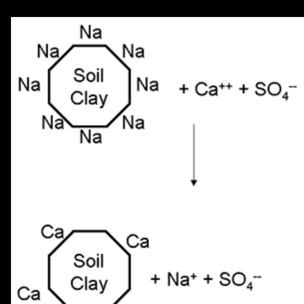


USDA Salinity Handbook

Gypsum Remediation of Soil

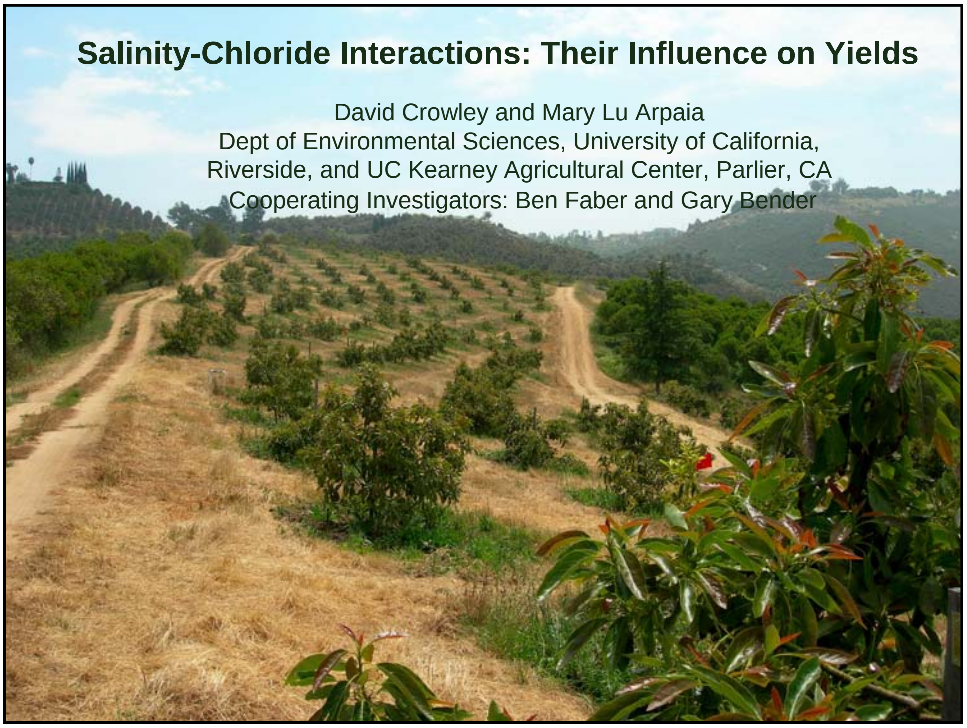


Gypsum -
Calcium Sulfate



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



Typical Soil Water Analysis for Well Water San Diego County

SUBMITTED BY: CROWLEY, DAVID
DANR SECTION: AGF: ENV SCI, UCR
COMMODITY: Avocado Irrigation Water

WORK REQ #: 03W003
OF SAMPLES: 2
DATE RECEIVED: 07/08/02
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)

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

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.**

Are there interactive effects of salinity TDS and Cl?

Plant responses

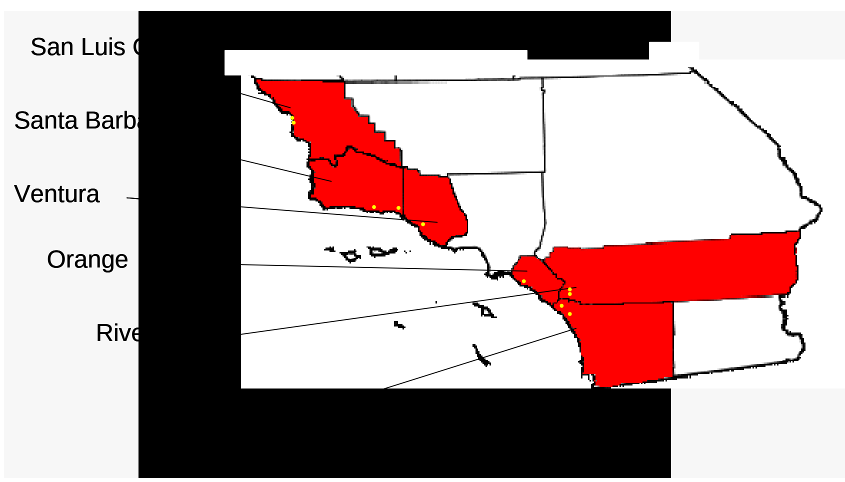
Dissolved Solids | **Chloride**

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?

Orchard Locations



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

Experimental Variables to be 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

Project Time Line

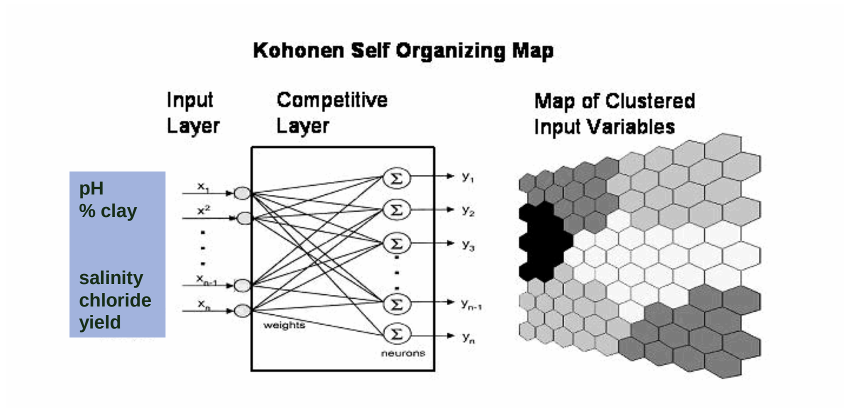
Activity	Schedule Date
Irrigation uniformity check	July – Aug 2008
Irrigation monitoring and site visits	Continuous
Tree selection and permanent tagging	July – August 2008
Leaf, soil, root density sampling	Sept – Oct 2008
Tissue, soil, water chemical analyses	Nov 08 – Jan 09
Fruit harvest data collection	Jan – April 2009
Statistical analyses completed Year 1	May – June 2009
Install Additional Sites	Jan – March 2009
Repeat Above Activities	Years 2009 - 2011

Work Plan:
Quantification of Root Growth Responses to Salinity Stress

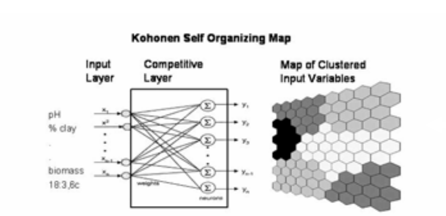
Data Collection:
- Root biomass / root length measurements
- Coarse, medium, fine roots

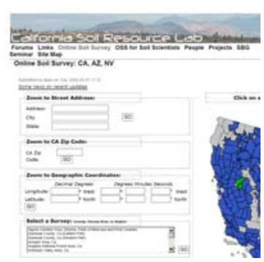
0 – 15 cm soil cores, sampled in September

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



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.

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.