Managing Pistachio Tree Health Under Saline Conditions

Advances in Pistachio Production – Short course

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9th Advances in PISTACHIO PRODUCTION

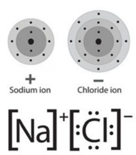
November 16, 2020

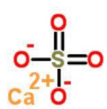
Pistachios are salt tolerant but elevated salinity….

- **degrades soil structure**
- **decreases water uptake**
- **stunts growth**
- **can lead to salt accumulation in tissues and decrease nut crop quality**
- **tree nutrition, soil, and water monitoring and management is key!**

What is salinity?

Dissolved salts in irrigation water or soil solution





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

Anions: SO_4^{2-}, Cl^{-}, $\mathbf{HCO_3^{-}}$, CO_3^{2-}, NO_3^{-}

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

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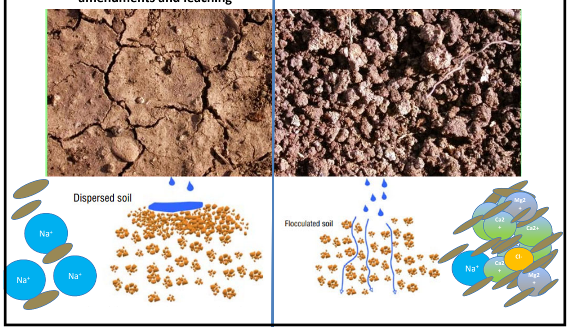
Saline-sodic or sodic soil
crusting/infiltration issues
high sodium, pH and bicarbonates
managed with soil and water amendments and leaching

Normal or saline soil
little to no infiltration problems
generally good soil structure
managed with leaching water

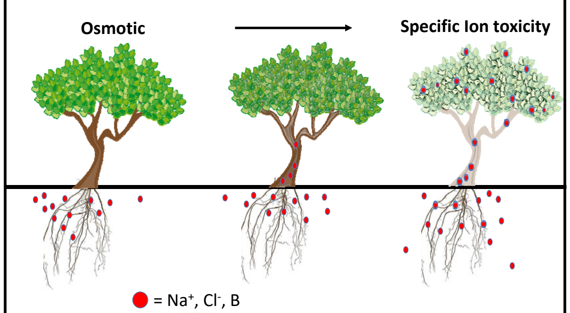


Salinity impacts on pistachio

Osmotic:
-Elevated salts require more energy to move water from roots to transpiring tissues
-ET decreases
-Growth limited

Specific Ion Toxicity:
-Salts absorbed by roots accumulate in woody tissue and leaves
-Leaf burn on margins
-Nutritional disorders

Tree sensitivity increases with time



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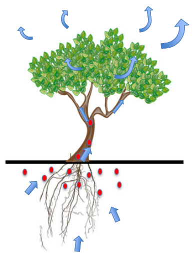
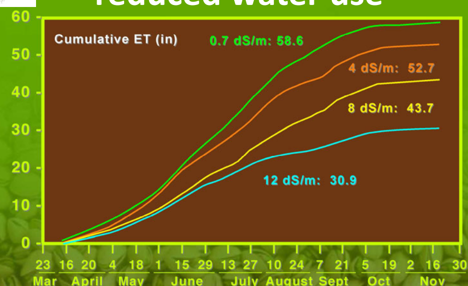
Mechanisms of salt tolerance

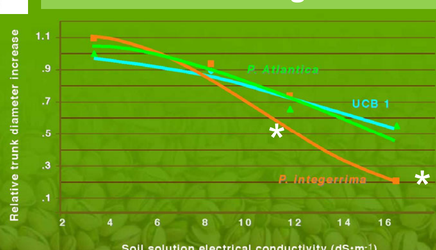


- High salt in soil leads reduces water potential between the soil and tree
- Tree makes physiological adjustments to maintain osmotic gradient for water movement from root to transpiring tissues
  - high energy cost
  - reduced vigor
- Na^+ and Cl^- (to a lesser extent) concentrations decrease along the transpiration stream through tree
- salt storage in the stem's xylem structures and circulation in the phloem to prevent ions accumulation in leaves (Godfrey et al. 2019)

Osmotic impacts: reduced water use

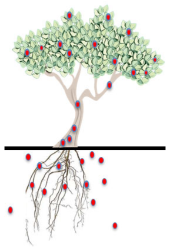


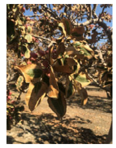
Osmotic impacts: reduced vigor



Ferguson, Poss, Grattan, Grieve, Wang, Wilson, Donavan, Chao. 2002 JASHS 127 (2): 194-199

Tree sensitivity increases with time





Prolonged or severe salinity may overcome trees ion exclusion strategies, leading to leaf necrosis and declining yields

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Specific Ion Impacts:

B levels in leaf tissue of Kerman scion

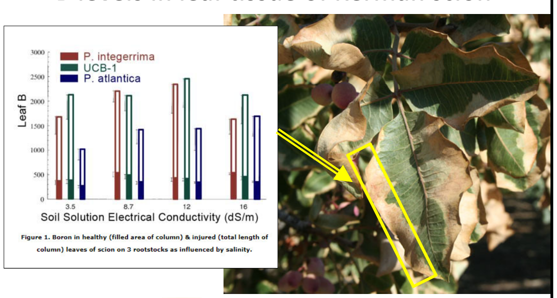

Figure 1. Boron in healthy (filled area of column) & injured (total length of column) leaves of scion on 3 rootstocks as influenced by salinity.

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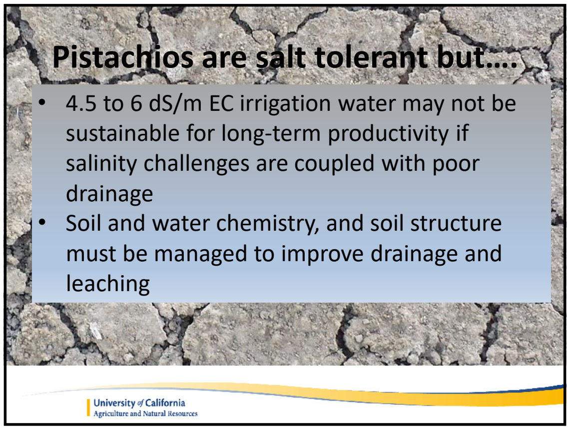
Yield Impacts


Pistachios are salt tolerant but….
• 4.5 to 6 dS/m EC irrigation water may not be sustainable for long-term productivity if salinity challenges are coupled with poor drainage
• Soil and water chemistry, and soil structure must be managed to improve drainage and leaching
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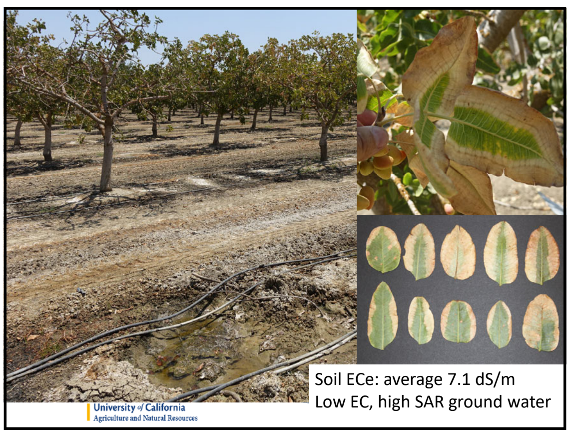
Soil ECe: average 7.1 dS/m
Low EC, high SAR ground water
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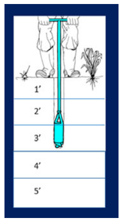
Dormant Season Salinity Management:
improve water penetration and leach enough salt for efficient use of water next season

Salinity Management Timeline:



November:

Sample irrigation water and soil from 1' to 5'
Determine EC, pH, Na^+ (SAR), B
Calculate and apply soil and/or water amendments if needed
Calculate depth of reclamation: Determine depth of water (inches per foot depth soil) needed to achieve desired salinity
Determine timeline for completing leaching program

November to March:

Leach in dormant season
1st fill profile to field capacity (3-6 inches over 3-4 days), then 2-4 days drainage.....then begin leaching applications

March:

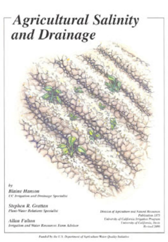
Re-sample irrigation water and soil from 1' to 5' to determine effectiveness of applied leaching and starting point for growing season

Key things to look for in water and soil analyses:

Analysis	Threshold for caution
pH	> 8 acidifying amendments likely necessary
EC (dS/m)	> 4.5 water, > 6-8 soil (potential reduced vigor and production)
Saturation percentage (Sat %)	Soil texture estimate
Na^+ and Cl^- (meq/L)	> 20* soil and water
Boron (mg/L)	> 3 soil and water
SAR water	> 5x EC_w likely infiltration problems
Exchangeable sodium % soil	> 6% likely infiltration problems
Bicarbonates (HCO_3^-) water (meq/L)	> 2.5, acid forming amendments recommended
% Lime ($CaCO_3^-$) soil	<1% add Ca amendments, >1% use acid forming amendments

*Sanden, B.L., L. Ferguson, H.C. Reyes, and S.C. Grattan. 2004.

Resources:



MANAGING SALINITY, SOIL AND WATER AMENDMENTS

Blake Sanden, Allan Fulton and Louise Ferguson

http://cekern.ucanr.edu/files/98609.pdf

ANALYTICAL CONVERSIONS AND LEACHING CALCULATIONS

Analytical Conversions and Leaching Calculations 12-17

http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3375

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Soil salinity amendment, unit conversions and leaching calculations

Cnvrsn-Infilt-LeachCalc

http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

Key Salinity measurements: EC and TDS

Electrical Conductivity (EC) (soil and water)

- driven by concentration of salts
- some ions conduct electricity more than others
- Units: deciSiemens per metre (dS/m) and millimho per centimeter (mmho/cm)
- *1 dS/m = 1 mmho/cm*

Total dissolved solids (TDS) water

- total mg of salt remaining if one-liter water evaporated to dryness
- Units: *(mg/L or ppm)*

Convert EC to TDS, or vice versa:
TDS (mg/L or ppm) = EC (dS/m) x 640 **(EC from 0.1 to 5 dS/m)**
TDS (mg/L or ppm) = EC (dS/m) x 800 **(EC 5 to 10 dS/m)**

Soil and water analyses unit conversions: meq/l, mg/l, ppm…

- Milligrams per liter (mg/L) = parts per million (ppm)
- mg/L = milliequivalents per liter (meq/L) × equivalent weight
- meq/L = mg/L ÷ equivalent weight

Equivalent weights of selected ions

Constituent	Equivalent weight
Sodium (Na^+)	23
Calcium (Ca^{2+})	20
Magnesium (Mg^{2+})	12
Ammonium (NH_4^+)	18
Potassium (K^+)	39
Bicarbonate (HCO_3^-)	61
Carbonate (CO_3^{2-})	30
Chloride (Cl^-)	35
Sulfate (SO_4^{2-})	48
Nitrate (NO_3^-)	62
Phosphate ($H_2PO_4^-$)	97

CONVERSION CALCULATIONS FOR SOIL EXTRACT AND WATER QUALITY EVALUATION

Sample Site	Total Salts TDS (ppm, mg/l)	pH	Ca mg/l	Mg mg/l	Na mg/l		HCO3 mg/l	SO4 mg/l	Cl mg/l	F mg/l	NO3 mg/l	B mg/l
Example	3120	7.6	347	91	482		210	1410	450	0.3	13	4.5
Enter Your			240									
Samples Here												

Sample Site	EC dS/m	pH	Ca meq/l	Mg meq/l	Na meq/l	SAR	HCO3 meq/l	SO4 meq/l	Cl meq/l	F mg/l	NO3 mg/l	B mg/l
Example	4.9	7.6	17.4	3.8	21.0	6.4	3.4	14.7	12.9	0.3	13	4.5
Results for	0.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Your Samples	0.0	0.0	0.0	0.0	0.0	#DIV/0!	0.0	0.0	0.0	0	0	0

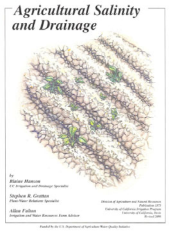
http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

Calculate soil applied rates

Simplified Goal: replace Na^+ with Ca^+ and leach the Na^+ out

- determine calcium requirement (**meq Ca/100 g soil needed to displace Na^+**) and amendment rates from soil analysis, use:
  - SAR
  - Exchangeable sodium
  - Exchangeable sodium percentage (ESP)
  - CEC

Example Calculations: see Hanson and Gratton pages 116-118



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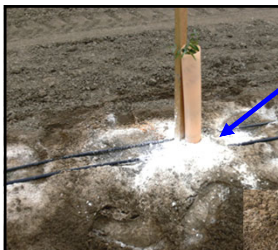


Broadcasting or injecting gypsum into the water is only necessary if: Sodium > 5*Calcium

Gypsum is a salt adds to osmotic pressure that limits water uptake through the roots

Calculate soil applied rates

Tons of material per acre foot soil

meq Ca/100 g soil	Gypsum (100%)	Sulfuric Acid	Sulfur (100%)	Lime sulfur (9% Ca, 24%S)
1	1.7	1.0	0.3	1.4
1.5	2.6	1.6	0.5	2.1
2	3.4	2.1	0.7	2.8
2.5	4.2	2.6	0.8	3.5
3	5.2	3.2	1.0	4.2
3.5	6.0	3.7	1.2	4.9
4	6.9	4.2	1.3	5.6

Adapted from Hanson and Gratton University of California, Pub 3375. 2006.

Caution: do not exceed 1500 lbs in a single application in established orchards

Calculate water applied rates

lbs of amendment per acre ft water

meq/L Ca	Gypsum (23%Ca, 19%S)	Sulfuric Acid 100% S	Sulfur 100% S	Lime sulfur (9% Ca, 24% S)	Nitro sulfur (20% N, 40%S)	Nphuric (10%N 18%S)	
1.0	234	133	44	191	109	242	Low to moderate rate
2.0	468	266	87	382	218	484	
3.0	702	399	131	573	327	726	
4.0	936	532	174	764	436	968	Moderate to high rate
5.0	1170	665	218	955	545	1210	
6.0	1404	798	262	1146	654	1452	

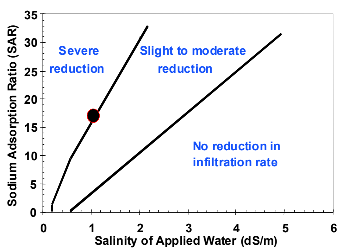
$EC_w = (Na^{+} + Ca^{++} + Mg^{++}) \div 10$

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

Need Ca^{++} to raise EC_w and lower SAR

Example water meq Ca/L calculations in Pistachio Production Manual p. 148 – 149

Calculate Amendment Rates



Analysis:

	Well 1	
pH	8.4	
EC_w	1.0	dS/m
Ca	0.5	meq/l
Mg	0.1	meq/l
Na	9.6	meq/l
HCO_3	4.2	meq/l
CO_3	1.0	meq/l
Cl	4.6	meq/l
SO_4	0.1	meq/l
B	0.7	mg/l
NO_3	5.2	mg/l
SAR	17.5	
SAR_{adj}	16.6	

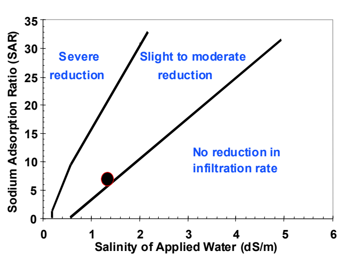
Na + Ca + Mg = 9.6 + 0.5 + 0.1 = 10.2 meq/l

EC = 10.2 ÷ 10 = 1.0 dS/m

SAR = 9.6 ÷ ((0.5 + 0.1) ÷ 2)^$^{0.5}$ = 17.5

See Pistachio Production Manual pages 148 – 149

Calculate Amendment Rates



Analysis:

	Well 1
pH	8.4
EC_w	1.3
Ca	3.5
Mg	0.1
Na	9.6
HCO_3	4.2
CO_3	1.0
Cl	4.6
SO_4	0.1
B	0.7
NO_3	5.2
SAR	7.2

New Ca + Mg = 3.5 + 0.1 = 3.6 meq/l

New cation concentration = 9.6 + 3.6 = 13.2 meq/l

New EC = 13.2 ÷ 10 = 1.3 dS/m

New SAR = 9.6 ÷ ((3.5 + 0.1) ÷ 2)^$^{0.5}$ = 7.2

Calculate water applied rates

lbs of amendment per acre ft water

meq/L Ca	Gypsum (23%Ca, 19%S)	Sulfuric Acid 100% S	Sulfur 100% S	Lime sulfur (9% Ca, 24% S)	Nitro sulfur (20% N, 40%S)	Nphuric (10%N 18%S)	
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$EC_w = (Na^+ + Ca^{++} + Mg^{++}) \div 10$

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

Need Ca^{++} to raise EC_w and lower SAR

Example water meq Ca/L calculations in Pistachio Production Manual p. 148 – 149

Calculate the depth of reclamation

CALCULATING LEACHING DEPTH TO ACHIEVE DESIRED SALINITY FOR SOIL RECLAMATION
(Using fresh water with EC <= 1 mmho/cm)

CALCULATING SAR, ESP AND DESIRED LEACHING DEPTH

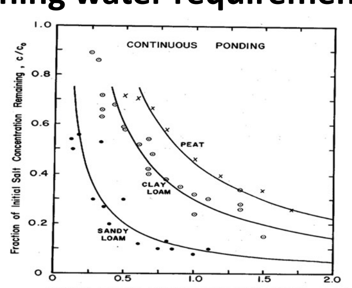
EXAMPLE Depth	Sample Thickness (inches)	SP (%)	pH	EC (dS/m)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR	ESP	EC/ESP	Desired Salinity	Dsrd/Orig EC	Sprinkling / Drip to Leach Rootzone (ft water / ft soil)	Sprinkling / Drip to Leach Rootzone (inch water for sample)
0-1'	12	40	7.9	5.5	34.2	4.6	21.7	4.9	5.7	1.0	3	0.55	0.28	3.30
1-2'	12	45	8.0	6.7	29.9	4.3	39.6	9.6	11.4	1.7	3	0.45	0.34	4.02
2-3'	12	45	8.0	7.3	25.1	4	51.8	13.6	15.8	2.2	3	0.41	0.37	4.38
TOTAL DEPTH OF LEACHING REQUIRED (inches):														11.70

ENTER YOUR DATA BELOW

YOUR SOIL Depth	Sample Thickness (inches)	SP (%)	pH	EC (dS/m)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR	ESP	EC/ESP	Desired Salinity	Dsrd/Orig EC	Sprinkling / Drip to Leach Rootzone (ft water / ft soil)	Sprinkling / Drip to Leach Rootzone (inch water for sample)
								#####	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!
								#####	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!
								#####	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!
TOTAL DEPTH OF LEACHING REQUIRED (inches):														#DIV/0!

http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

Soil texture and depth of leaching water requirement



Calculate depth of water for reclamation

Depth	SP	pH	EC	Ca	Mg	Na	SAR	ESP
0-1'	40	7.9	5.5	34.2	4.6	21.7	4.9	5.7
1-2'	45	8.0	6.7	29.9	4.3	39.6	9.6	11.4
2-3'	45	8.0	7.3	25.1	4	51.8	13.6	15.8

Average salinity: 6.5 dS/m

Required Leaching Ratio* (depth water/depth soil)
= K / (Desired EC/Original EC)
* Assumes leaching water is ≈1.0 dS/m

Use K factor of 0.15 for sprinkling, drip or repeated flooding.
Boron use 0.6 leaching coefficient 3x greater than other salts

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Calculate depth of water for reclamation

Required Leaching Ratio* (depth water/depth soil)
= K / (Desired EC/Original EC)
* Assumes leaching water is ≈1.0 dS/m

Use K factor of 0.15 for sprinkling, drip or repeated flooding.
Boron use 0.6 leaching coefficient 3x greater than other salts

Required Leaching Ratio (depth water/depth soil) =
0.15/(**3/6.5**) = 0.325

Actual depth of leaching water = 0.325 * 3 feet = **0.98 feet**

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Table 3 CONCENTRATION FACTORS (X) FOR PREDICTING SOIL SALINITY (ECe)1 FROM IRRIGATION WATER SALINITY (ECw) AND THE LEACHING FRACTION (LF)

Leaching Fraction (LF)	Applied Water Needed (Percent of ET)	Concen-tration Factor (X)
0.05	105%	3.2
0.1	111%	2.1
0.15	118%	1.6
0.2	125%	1.3
0.25	133%	1.2
0.3	143%	1
0.4	167%	0.9
0.5	200%	0.8
0.6	250%	0.7
0.7	333%	0.6
0.8	500%	0.6

Applied water needed = 1/(1-LF)

Ayers, R.S., D.W. Westcot. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1, Reprinted 1989, 1994. http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm

In-season leaching fraction to maintain desired rootzone salinity

Leaching fraction required over long-term irrigation with a given salinity of water to obtain a desired rootzone salinity. (Ignoring precipitation/dissolution reactions in the soil.)

Irrigation Water EC (dS/m)	Desired Average Rootzone ECe 1	2	3	4	5	6	7
0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.4	0.07	0.02	0.01	0.01	0.01	0.00	0.00
0.8	0.23	0.07	0.04	0.02	0.02	0.01	0.01
1.2	0.44	0.14	0.07	0.05	0.03	0.02	0.02
1.6		0.23	0.12	0.07	0.05	0.04	0.03
2.0		0.33	0.17	0.10	0.07	0.05	0.04
2.4		0.44	0.23	0.14	0.10	0.07	0.06
2.8			0.29	0.18	0.13	0.09	0.07
3.2			0.36	0.23	0.16	0.12	0.09
3.6			0.44	0.27	0.19	0.14	0.11
4.0				0.33	0.23	0.17	0.13
4.4				0.38	0.26	0.20	0.15
4.8				0.44	0.30	0.23	0.18
5.2					0.35	0.26	0.20
5.6					0.39	0.29	0.23
6.0					0.44	0.33	0.25
6.4						0.36	0.28

SOLVING FOR DESIRED LEACHING FRACTION DIRECTLY:

Regressing the rootzone salinity concentration factors in FAO29 and rearranging to solve for Leaching Fraction (LF):

LF = 0.326 (Desired ECe/ECirr)^ -1.64

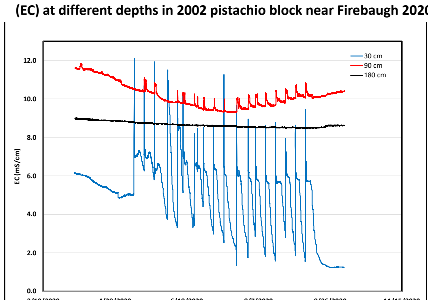
Calculated feet to hours

- Gallons to apply = depth of water (inches) x (trees per acre) X (0.622 gal/in. ft^2)
- Depth of water inches = 0.98 feet x 12 inches per foot = **11.8 inches**
- Acre inches per hour = (trees per acre) x (gph output per tree) ÷ 27,154 gallons per acre-inch)
- 128 trees x 8 gph ÷ 27,154 gallons = **0.038 acre in/hr**

11.8 inches ÷ 0.038 in/hr = 310 hours or 13 days

Monitoring progress with continuous soil EC measurements:

The effect of micro-spray application of non-saline water on soil electrical conductivity (EC) at different depths in 2002 pistachio block near Firebaugh 2020



(Banuelos et al., unpublished)

Tree health in saline conditions summary…..

- **Pistachio is more tolerant than other tree crops but elevated salinity degrades soil structure, decreases water uptake, stunts growth, eventually accumulates salt in tissues and decreases nut crop quality**

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Tree health in saline conditions summary…..

- Keep soil salt levels below 4.5 dS/m
- Soil and water sample
- First address sodicity then salinity
  - Fall apply gypsum before rain and leaching
- Best approach: leach salts in dormant period -lowest ET and maximum salt accumulation post season
- If possible complete leaching before spring root flush

THANK YOU!

QUESTIONS?

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