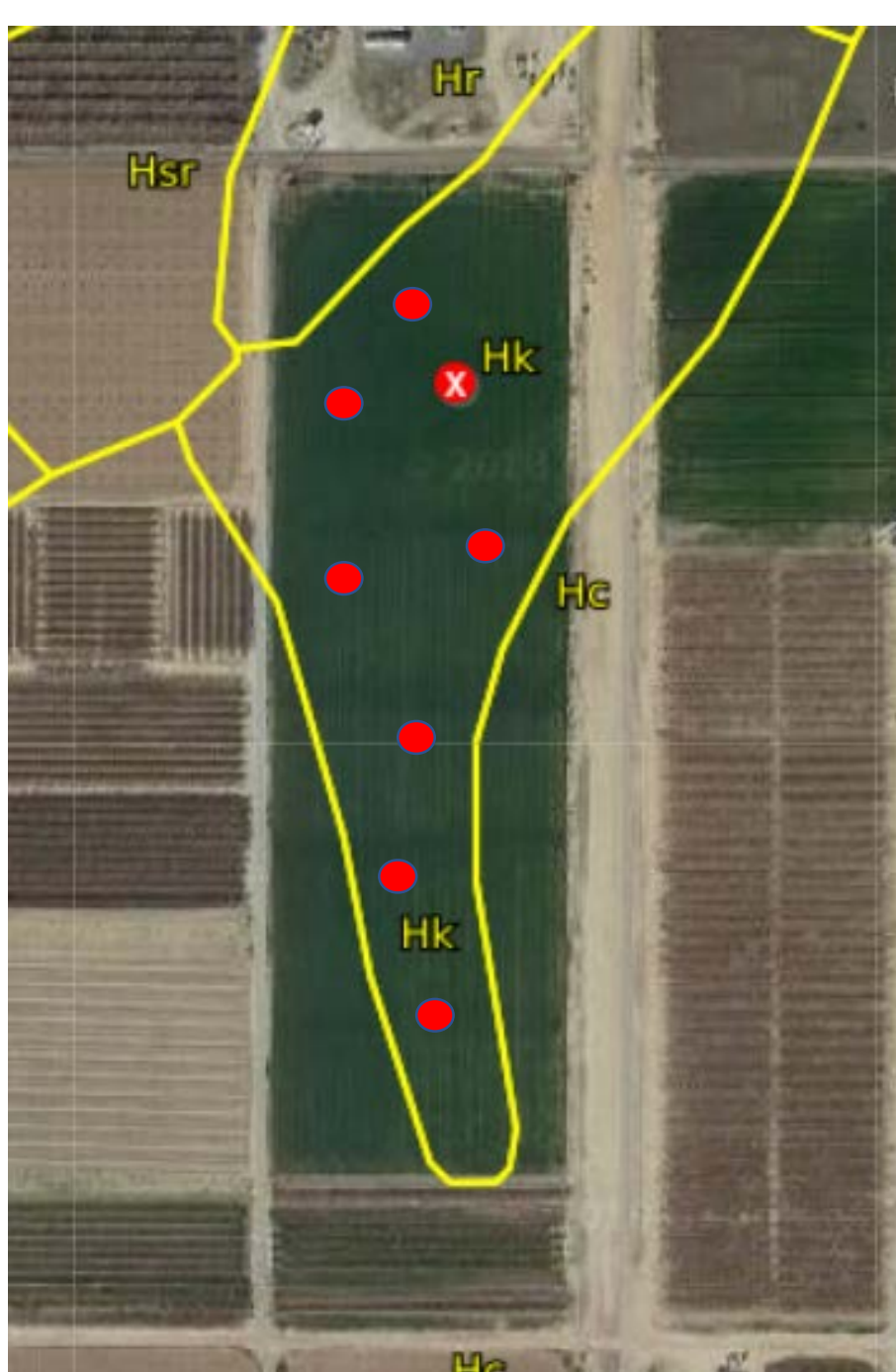


Evaluation of Soil Salinity, and Soil and Water Reports

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Regular Soil Sampling

- When soil sampling, keep samples to a soil type
- Sub-sample multiple areas in the field and combine them for one composite sample
 - Don't combine good and bad areas
- Sample *in the wetted zone* and standardize!
 - $\frac{1}{2}$ to $\frac{1}{3}$ of the radius of the wetted zone
 - Keep depth the same
 - Stay away from edges – salts build up there
 - MIX BEFORE SENDING TO A LAB

Sampling to understand soil salinity

- Sodium (and chloride) can be present in multiple areas in the soil
 - Shallow sodium, causing problems with infiltration
 - Sodium and chloride accumulated around the edges of wetted zones
 - Sodium and chloride leached deeper into the rootzone, but not leached *out* of the rootzone
- There have been oddball cases of salts being found fairly deep in the soil and affecting tree growth, so keep your mind open!
- Sampling for salinity should take these possibilities into account
 - Sample along the diameter of the wetted zone
 - Separate out the top few inches to see if salts are accumulating
 - Do deeper sampling to see if subsequent leaching is effective
- Standard nutrient sampling (1-12 inches, inside the wetted zone) can be great for initial exploration, but you will likely need to sample more!



- Pull water samples from every source you'll be using
- Pull well water samples after the pump has been running for at least 30 minutes
- Soil pH, ECe, Na, Cl, B will eventually look like your water whether it's from leaching or regular irrigation

Water Sampling

Almond leaf necrosis caused by sodium, chloride toxicity.
Courtesy of Blake McCullough-Sanden



What should you request
from a lab?

- Agricultural suitability test for water
 - Will cover everything you need for irrigation water, may not include what is necessary for FSMA
- Soil fertility test
 - Will cover what you need for general soil monitoring
- Saturated paste extract
 - Necessary for calculating gypsum requirements

Checking your lab water, salinity results for quality

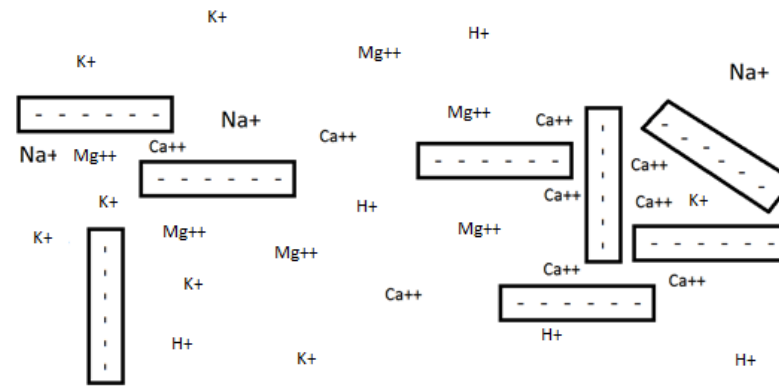
- Good: The lab reports saturated paste extracts in meq/L
- Good: The summed cations in meq/L (Ca + Mg + Na) are within 5 to 10% of the summed anions ($\text{HCO}_3 + \text{CO}_3 + \text{SO}_4 + \text{Cl}$)
- Good: The $\text{EC}_w \times 10$ is about the sum of the cations (Ca + Mg + Na) or anions ($\text{HCO}_3 + \text{CO}_3 + \text{SO}_4 + \text{Cl}$)
- Bad: If the values are exactly the same, some cations or anions could have been estimated
- Good: the lab will happily recheck any weird values. Everyone makes mistakes!

What do the units mean?

- Ppm: parts per million. A concentration. $1 \text{ ppm} = 1:1,000,000$
- %: percentage. A concentration $1\% = 1:100$
- Meq: milliequivalents. Used in soil lab analyses for measuring the CEC and ion activity; takes into account ion charge and molecular weight
 - When looking at activity, 1 ppm Ca is not the same as 1 ppm Na because Ca has a 2+ charge whereas Na has a 1+ charge
 - But when looking at activity, 1 meq Ca is the same as 1 meq Na
 - *this is important when looking at salinity as you leach based on meq you want to remove
- dS/m = mmohs/cm: A measurement that measures salt concentrations via the conductivity of a solution; does not differentiate between ions
 - Charged ions conduct electricity and water with more ions will conduct more electricity

Cation Exchange Capacity

- The CEC is a measure of a soil's capacity to retain cations (Ca^{2+} Mg^{2+} Na^+ K^+)
- It is generated on weathered clay particles and organic matter
- It is an inherent soil property



Soil and Water Salinity Guidelines

Parameter	Unit	Degree of Growth Restriction		
		None	Increasing	Severe
Root Zone ECe	dS m ⁻¹	< 1.5	1.5 – 4.8	> 4.8
Water ECw	dS m ⁻¹	< 1.1	1.1 – 3.2	> 3.2
SAR soil*		< 5.0	5.0 – 15.0	> 15.0
SAR water ⁺		< 3.0	3.0 – 9.0	> 9.0
Soil Chloride*	meq L ⁻¹	< 5.0	5.0 – 15.0	> 15.0
Water Chloride	meq L ⁻¹	< 4.0	4.0 – 10.0	> 10.0
Soil Boron*	mg/L	< 0.5	0.5 – 3.0	> 3.0
Water Boron	ppm or mg/L	< 0.5	0.5 – 3.0	> 3.0

*derived from a saturated soil extract

+Some labs may report adjusted SAR, which takes into account carbonate and bicarbonate levels

Water Infiltration into Soils

Table 5.5 Guidelines to predict infiltration problems, based on soil salinity or irrigation water quality.

Sodium adsorption ratio (SAR)	Potential for water infiltration problem to develop	
	Unlikely if EC_e or EC_w is	Likely if EC_e or EC_w is
0–3	>0.7	<0.3
3.1–6	>1.0	<0.4
6.1–12	>2.0*	<0.5
12.1–20	>3.0*	<1.0
20.1–40	>5.0*	<2.0

Source: Adapted from J. D. Oster et al. (1992), p. 67.

*Even though these salinity conditions are less likely to develop slow infiltration rates, the EC values exceed tolerable levels for almond.

- Water quality affects more than the buildup of salts
- Irrigation water/soils with high SAR *and* low EC can result in poor infiltration
- Irrigation water with extremely low EC_w *and* low SAR can result in poor infiltration

From: Micke, Warren C. *Almond production manual*. Vol. 3364. UCANR Publications, 1996.

Amending Salinity: Reclamation Leaching

Desired root zone salinity (dS/m)	Water required to leach initial salinity (inches water required per foot of root zone)			
	2.0	3.0	4.0	5.0
1.0	1.8	3.0	4.2	5.4
1.5	0.6	1.8	3.0	4.2
2.0	0.0	0.6	1.8	3.0

From: Micke, Warren C. *Almond production manual*. Vol. 3364. UCANR Publications, 1996.

- **Assumes $EC_w < 1.0$ dS/m**
- **Soils will never be less salty than the water they're leached with**
 - Unless you use rainfall as part of your applied water
- Assumes leaching is done over several small applications, with at least 2 days of drainage in between
- With a 5-foot root zone with an average EC_e of 4.0 dS/m, to reduce salinity to 1.0 dS/m, you need 21 inches of water
 - Excludes water lost through evaporation or plant water uptake

Amending Salinity: Amendment Additions

- Sodium must be displaced from the CEC with another positively charged cation, ideally calcium
- Sources of calcium: gypsum, lime
- If your soil has a calcium-based free lime, you can add acids, which will break down the free lime and release calcium

Table adapted from: Ferguson, L. and Haviland, D., 2016. *Pistachio production manual* (Vol. 3545). UCANR Publications.

Chemical Name	Trade name: composition	Lbs/ac-6 in to replace 1 meq/l Na	Lbs/ac-ft of water to get 1 meq Ca
Sulfur	Soil sulfur: 100% S	321	43.6
Gypsum	Gypsum: 23.3% Ca	1720	234
Potassium thiosulfate	KTS: 25% K ₂ O, 26% S	1890 (Assuming K replaces Na in addition to the S)	256
Sulfuric acid	100% H ₂ SO ₄	981	133

Other SoilTest Components

General Fertility or Saturated Paste test:

Type	Results
pH	6.7
CEC	13.1
Sat. Percentage	43%

- pH: Measure of the number of hydrogen ions in solution
 - Useful for determining amendments, if needed
 - Useful for managing micronutrient applications
- CEC: Cation Exchange Capacity; measure of cation binding sites
 - Directly related to amount and type of clay
 - Useful for calculating gypsum amendments
- Saturation percentage: how much water needed to saturate soil
 - Can be used to estimate texture

Other Soil Test Components

General fertility test:

Nutrient	Results (ppm)	Results (%CEC)
Calcium	2000	36.93
Magnesium	1410	42.91
Potassium	176	1.67
Sodium	883	14.21

Saturated Paste Extract:

Nutrient	Results (ppm)	Results (meq/L)
Calcium	200	9.9
Magnesium	141	11.6
Potassium	17	0.4
Sodium	88	13.8

- Cations can be reported as ppm or as a percentage of the cation exchange capacity, or meq/L (in saturated paste tests)
- I personally don't find ppm to be very useful unless you manage very few sites
- %CEC gives you an idea as to the effect these cations have on your soil
 - Sodium > 5% CEC can mean trouble
 - Potassium < 2% CEC could mean low availability
- Meq/L is needed for calculating gypsum requirements, but no standards exist for predicting plant response to nutrients based on saturated paste tests
 - That doesn't mean you can't develop your own for your own soils

Other Soil Test Results to look for

General fertility test:

Nutrient	Result (ppm)
Nitrate-N	3 ppm
Phosphorus	5 ppm
Zinc	2 ppm
Iron	6 ppm
Copper	1 ppm
Manganese	2 ppm

- ALWAYS monitor for deficiencies via leaf tissue analysis!
- Nitrate: negatively charged and does not stay in soils
 - could be used as a pre-season or post-harvest check to adjust N application rates
- Phosphorus: not much research showing growth response
- Zinc: foliar applications are standard; apply to the soil only if pH is low and trees are deficient
- Copper, iron, manganese: deficiency is rare

Irrigation water reports

Parameter	Result	units
pH	7.5	
Na	1.05	Meq/L
Ca	1.34	Meq/L
Mg	0.75	Meq/L
CO ₃	0.0	Meq/L
HCO ₃	2.37	Meq/L
Cl	0.40	Meq/L
EC _w	0.4	dS/m
B	0.08	Ppm
SAR _{adj}	1.02	

- Sodium, chloride, boron, EC_w all acceptable for almond production
- CO₃, HCO₃ : carbonates and bicarbonates; present in water with high pH
 - Ca+Mg >2; HCO₃ >2 *could* indicate precipitation issues
- SAR: sodium absorption ratio
- Adjusted SAR: takes into account CO₃ and HCO₃ (and by extension the Ca and Mg); could be much higher than SAR

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