INTERPRETING SOIL & LEAF ANALYSES

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CALIFORNIA AVOCADO SOCIETY
SEMINAR SERIES
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- Understanding a basic soil test
  - Soil test basics
  - Terms and definitions
  - Interpreting a soil analysis

- Understanding a basic leaf analysis
  - Leaf analysis basics
  - Optimum ranges
  - Interpreting a leaf analysis

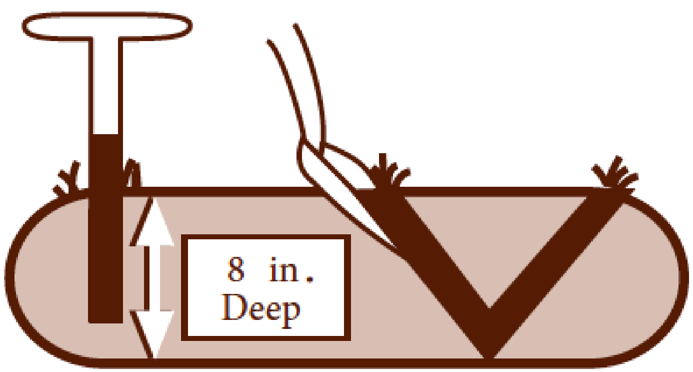
- Understanding a basic irrigation water analysis

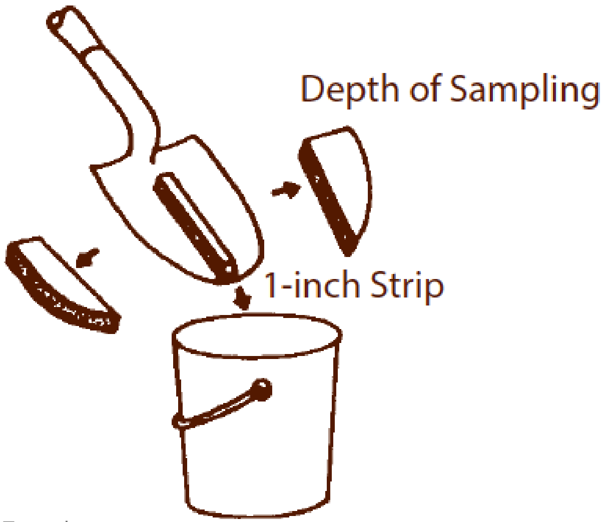
SOIL TEST BASICS

- When should a soil sample be collected for analysis?
  - Before you plant a grove
  - At least every couple of years for an established grove
  - Timing isn't critical, but consistency from year-to-year is
  - Spring sampling is typical, but sampling with leaf analyses in the fall can aid in interpretation

SOIL TEST BASICS

- How should a soil sample be collected?
  - For open ground, base your sampling on variability (soil textures, slope, aspect)
  - Sample from the rootzone – 0-8 inches for avocados
  - Sample approximately halfway between trunk and canopy edge
  - Collect a composite sample from each irrigation block and/or soil type
    - Use a soil probe or shovel to collect individual samples
    - Place samples in a clean 5-gallon bucket and mix thoroughly
    - Variability dictates the number of samples to collect (10-20 is typical)





Adapted from: H.J. Savoy. 2017. Soil Testing (PB1061), University of Tennessee Cooperative Extension

SOIL ANALYSIS RESULTS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation
Primary Nutrients				Very Low / Moderately Low / Optimum / Moderately High / Very High
Nitrate-Nitrogen	4.0	PPM	22 - 32	
Phosphorus	43	PPM	20 - 35	
Potassium (Exch)	410	PPM	110 - 680	
Potassium (Sol)	0.851	meq/L	0.92 - 2.9	6%
Secondary Nutrients				
Calcium (Exch)	3150	PPM	3500 - 4600	
Calcium (Sol)	5.27	meq/L	3.7 - 9.7	
Magnesium (Exch)	1460	PPM	350 - 700	
Magnesium (Sol)	6.70	meq/L	2.8 - 5.8	
Sodium (Exch)	70	PPM	0.0 - 330	
Sodium (Sol)	2.50	meq/L	0.0 - 15	
Sulfate	4.39	meq/L	1.4 - 21	
Micro Nutrients				
Zinc	55.0	PPM	1.9 - 42	
Manganese	27.9	PPM	3.2 - 64	
Iron	28.1	PPM	19 - 60	
Copper	2.3	PPM	0.56 - 11	
Boron	0.28	PPM	0.42 - 2.2	
Chloride	3.74	meq/L	0.21 - 4.8	
CEC	29.0	meq/100g	14 - 35	
% Base Saturation				
CEC - Calcium	54.1	%	60 - 80	
CEC - Magnesium	41.4	%	10 - 20	
CEC - Potassium	3.59	%	1.0 - 6.0	
CEC - Sodium	1.01	%	0.0 - 5.0	
CEC - Hydrogen	< 1.00	%	0.0 - 3.0	
				Strongly Acidic / Moderately Acidic / Near Neutral / Moderately Alkaline / Strongly Alkaline
pH	7.39	Units	6.0 - 7.5	
Others				Satisfactory / Possible Problem / Moderate Problem / Increasing Problem
Soil Salinity	1.19	dS/m	0.0 - 2.0	
SAR	1.0		0.0 - 6.0	
Limestone	< 0.10	%	0.0 - 0.50	
				0 / 1 / 2 / 3 / 4 / 5 / 6
Lime Requirement	0	Tons/AF	---	
				Very Low / Moderately Low / Optimum / Moderately High / Very High
Moisture	37.3	%	5.5 - 38	
				Loamy Sand / Sandy Loam / Loam / Silt Loam / Clay Loam / Clay / Organic
Saturation	55.0	%	40 - 50	

Good — Problem — Indicates physical conditions and/or phenological and amendment requirements.

Hass Soil Analysis - Primary and Secondary Nutrients

Sample Area	Variety	PPM Nitrate-N	PPM Phosphorus	PPM Exch. K	meq/L Sol. K	PPM Exch. Ca	meq/L Sol. Ca	PPM Exch. Mg	meq/L Sol. Mg	PPM Exch. Na	meq/L Sol. Na	meq/L Sulfate
SA-1 Block 1 West Hass	Hass	119	16	140	0.921 (2%)	2810	28.6 (60%)	280	11.0 (23%)	40	6.82 (14%)	17.5
SA-2 Block 1 East Hass	Hass	7.1	11	180	1.14 (4%)	2360	14.3 (52%)	309	7.40 (27%)	40	4.67 (17%)	13.4

Hass Soil Analysis - Micro Nutrients and Base Saturation

Sample Area	PPM Zinc	PPM Manganese	PPM Iron	PPM Copper	PPM Boron	meq/L Chloride	meq/100g CEC	% CEC - Ca	% CEC - Mg	% CEC - K	% CEC - Na	% CEC - H
SA-1 Block 1 West Hass	10.6	5.8	8.0	14.0	0.396	3.76	16.8	83.3	13.7	2.09	1.16	< 1.00
SA-2 Block 1 East Hass	17.2	11.2	7.4	12.6	0.334	2.23	15.0	78.7	16.9	3.11	1.11	< 1.00

Hass Soil Analysis - Additional Elements

Sample Area	Units pH	dS/m ECe	SAR	% Limestone	Tons/AF Lime Req	Moisture %	Moisture Low / Opt / High	% Saturation
SA-1 Block 1 West Hass	7.76	4.27	1.5	1.2	0	5.1		32.5 (Loam)
SA-2 Block 1 East Hass	7.66	2.10	1.4	1.1	0	9.0		36.5 (Loam)

Good — Problem — Low — High — Indicates physical conditions and/or phenological and amendment requirements.

TERMS AND DEFINITIONS

- PPM = parts per million – is a concentration value
  - 5 blue m&ms in a bowl of 1 million m&ms = 5 PPM blue m&ms
  - Average soils weigh 4 million pounds per acre-foot
  - Assuming most nutrient uptake is in the top 6-inches of soil
  - PPM x 2 = pounds per acre

- mg/L = milligrams per liter – is a concentration value equivalent to PPM
  - 1 L of water = 1,000 mL = 1,000 g
  - 1 mL of water = 1 g = 1,000 mg
  - 1,000 x 1,000 = 1,000,000 – a liter weighs 1 million mg

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Good — Problem   Low — High   Indicates physical conditions and/or phenological and amendment requirements.

TERMS AND DEFINITIONS

- meq/L = milliequivalents per liter – a measure of charge concentration per liter
  - Calcium – in soil solution calcium exists as Ca^{2+} (Ca^{++})
  - Calcium in soil has a charge of 2
  - An equivalent of an ion is the atomic mass of the ion divided by the charge
  - Ca has an atomic mass of 40.08, thus an equivalent of Ca is 40/2 = 20
    - Converting between meq/L and PPM
      - PPM = equivalent weight x meq/L
      - meq/L = PPM / equivalent weight
      - 28.6 meq/L Ca = 20 x 28.6 = 572 PPM Ca

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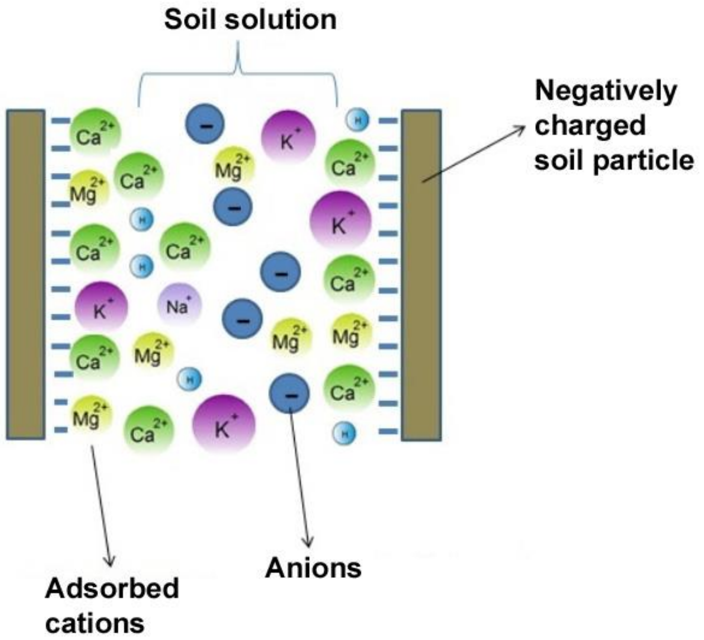
EQUIVALENT WEIGHTS OF COMMON IONS

Ion Type	Ion Name	Symbol	Atomic Mass	Equivalent Weight
Cations	Calcium	Ca^{2+}	40	20
	Magnesium	Mg^{2+}	24	12
	Sodium	Na^{+}	23	23
	Potassium	K^{+}	39	39
Anions	Bicarbonate	HCO_3^{-}	61	61
	Carbonate	CO_3^{2-}	60	30
	Chloride	Cl^{-}	35.5	35.5
	Nitrate	NO_3^{-}	62	62
	Sulfate	SO_4^{2-}	96	48

TERMS AND DEFINITIONS

- CEC = cation exchange capacity – a measure of the quantity of cations that can be held by a soil, reported as meq/100 g
  - Cations are held by the negative charges on clay particles and organic matter
  - Common cations are:
    - Calcium (Ca^{2+})
    - Magnesium (Mg^{2+})
    - Potassium (K^{+})
    - Ammonium (NH_4^{+})
    - Sodium (Na^{+})
    - Hydrogen (H^{+})
  - High CEC value = greater nutrient storage capacity of the soil
  - Cations in soil solution are in dynamic equilibrium with cations adsorbed on soil particles



TERMS AND DEFINITIONS

- Exchangeable nutrients – ions held on the soil complex that may be replaced by other ions of like charge.
  - Exchangeable nutrients are not leachable
- Soluble nutrients – ions in the soil solution that can be readily absorbed by plant roots.
  - Soluble nutrients are leachable

Hass Soil Analysis - Primary and Secondary Nutrients

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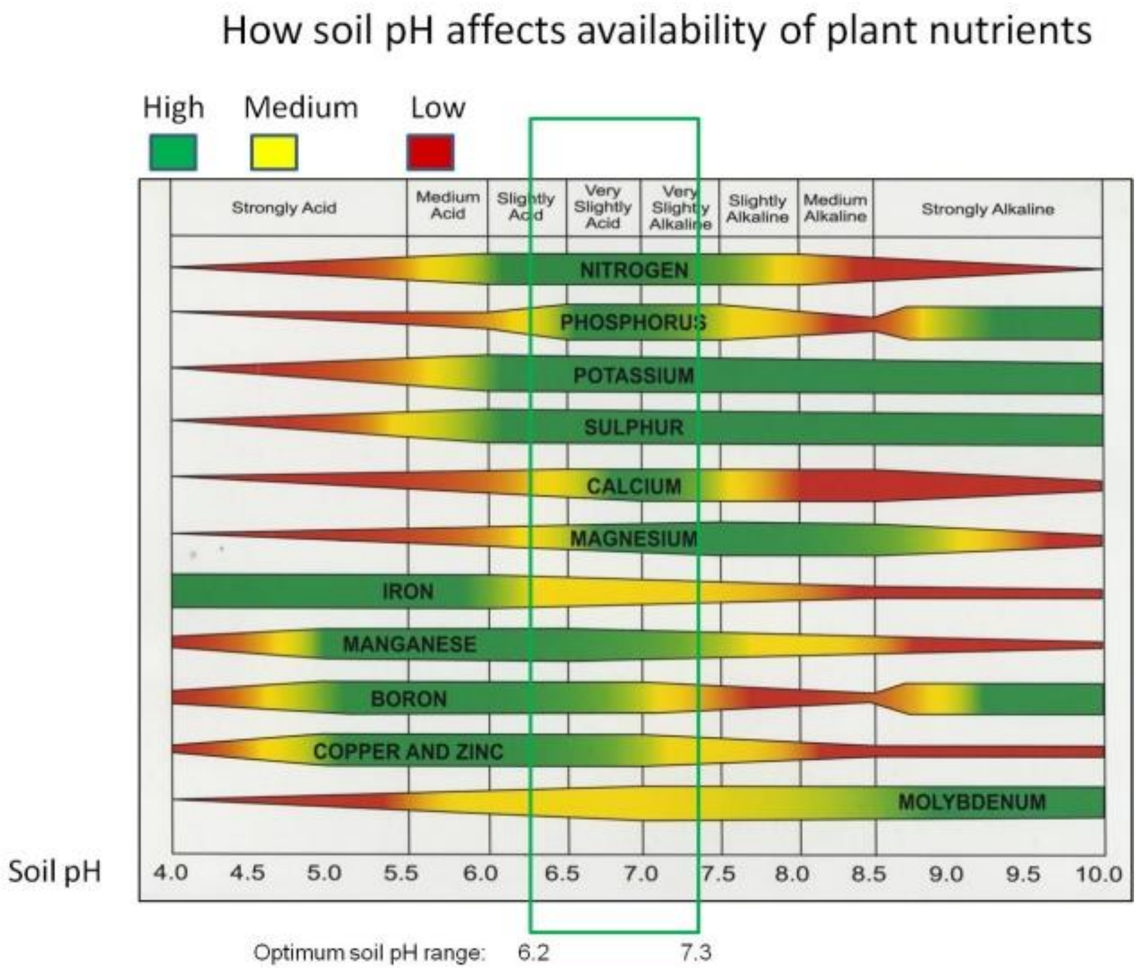
Good — Problem Low — High Indicates physical conditions and/or phenological and amendment requirements.

TERMS AND DEFINITIONS

- pH – a measure of acidity and alkalinity; a measure of the hydrogen ion concentration
  - Based on a log scale
    - a pH of 6 is 10x more acid than a pH of 7
    - a pH of 8 is 10x more alkaline than a pH of 7



TERMS AND DEFINITIONS

- EC – electrical conductivity; a measure of the salinity of a solution
  - Pure water does not conduct electricity, but water with salts dissolved in it does
    - A salt is a material that when dissolved in water (or soil solution) releases a cation and an anion
      - Sodium chloride (Na^+, Cl^-); calcium nitrate (Ca^{2+}, $2NH_3^-$); potassium nitrate (K^+, NH_3^-)
  - The more salts in a solution, the better it conducts electricity and the higher the EC
  - Reported as decisiemens per meter (dS/m)

- EC_e = extract EC – a measure of the EC of the soil solution extract

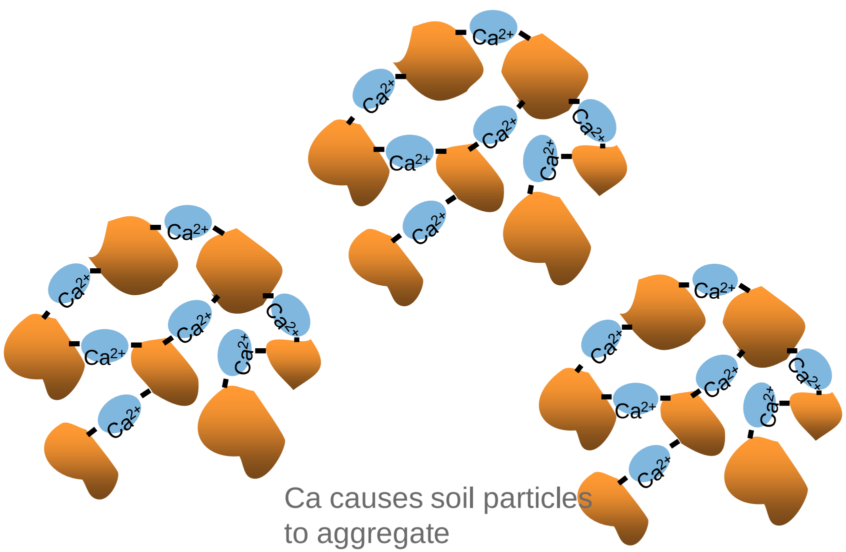
- EC_w = water EC – a measure of the EC of water

TERMS AND DEFINITIONS

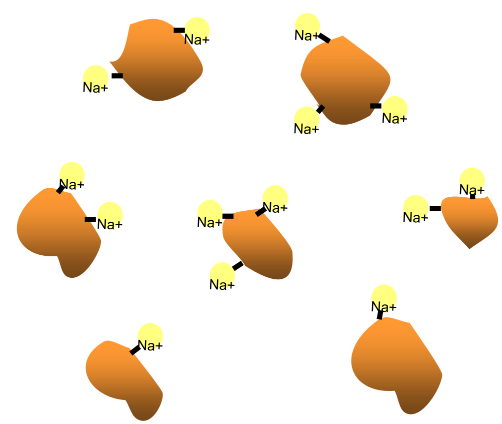
- SAR – sodium adsorption ratio – describes the relative activity of sodium (Na) ions to Ca and Mg in soil solution or water

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

  - As the SAR increases
    - permeability of soil decreases
    - the risk of sodium toxicity increases
  - SAR < 3 is desirable, not to exceed 4

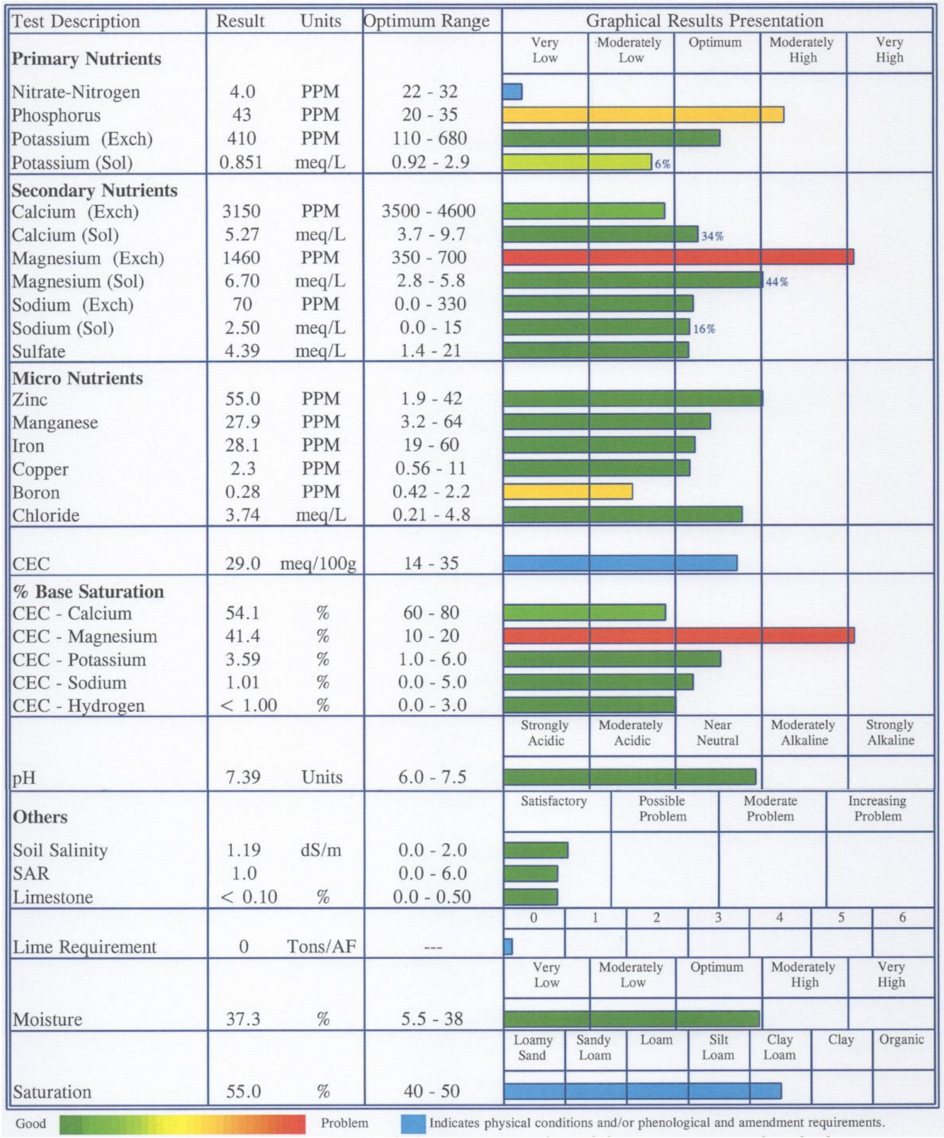


Ca causes soil particles to aggregate



Na causes soil particles to disperse

INTERPRETING A SOIL ANALYSIS



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Sodium (Exch)	70	PPM	0.0 - 330
Sodium (Sol)	2.50	meq/L	0.0 - 15
Sulfate	4.39	meq/L	1.4 - 21
Micro Nutrients			
Zinc	55.0	PPM	1.9 - 42
Manganese	27.9	PPM	3.2 - 64
Iron	28.1	PPM	19 - 60
Copper	2.3	PPM	0.56 - 11
Boron	0.28	PPM	0.42 - 2.2
Chloride	3.74	meq/L	0.21 - 4.8
CEC	29.0	meq/100g	14 - 35
% Base Saturation			
CEC - Calcium	54.1	%	60 - 80
CEC - Magnesium	41.4	%	10 - 20
CEC - Potassium	3.59	%	1.0 - 6.0
CEC - Sodium	1.01	%	0.0 - 5.0
CEC - Hydrogen	< 1.00	%	0.0 - 3.0
pH	7.39	Units	6.0 - 7.5
Others			
Soil Salinity	1.19	dS/m	0.0 - 2.0
SAR	1.0		0.0 - 6.0
Limestone	< 0.10	%	0.0 - 0.50
Lime Requirement	0	Tons/AF	---
Moisture	37.3	%	5.5 - 38
Saturation	55.0	%	40 - 50

- A soil test tells you:
  - The capacity of your soil to act as a reservoir of nutrients
  - Whether your nutrients will be available or unavailable (pH)
  - Potential salinity issues
  - Potential water infiltration issues

LEAF ANALYSIS BASICS

- Leaf analyses are a snapshot in time that tell you how well your nutrition program is working, comparing leaf analyses over time is very beneficial
- Sample in late summer to early fall (mid-August – mid-October)
- Sample healthy, mature, spring flush leaves (4 to 6 months old) from non-fruiting, non-flushing branches
  - Do not sample terminal leaves or the worst looking leaf on a branch
- Sample areas based on fertilization blocks (typically an irrigation block)
- Collect 30-40 leaves from across a block, being sure to take samples from all four quadrants of the trees (N, S, E, W)
  - Criss-crossing a block on several diagonals is a good way to ensure your sample represents the block
- Leaf samples should be stored in paper bags, not plastic, and stored at room temperature until delivery to the lab

OPTIMUM RANGES

- There is a debate about optimum ranges, they should be used as guidelines until you have developed a history for your grove

Nutrient	UC Range	Crowley Range*	Fruit Growers Lab
N%	1.6 – 2.3	2.25 – 2.5	2.2 – 2.4
P%	0.10 – 0.25	0.1 – 0.15	0.08 – 0.44
K%	0.75 – 2.0	0.7 – 0.9	1.0 – 3.0
Ca%	1.0 – 3.0	1.8 – 2.0	1.0 – 4.5
Mg%	0.25 – 0.80	0.6 – 0.9	0.25 – 1.0
S%	0.20 – 0.60	0.45 – 0.53	***
Cl%	< 0.25	**	< 0.25
Na%	< 0.25	**	< 0.25
B ppm	50 – 100	38 – 60	12 – 100
Zn ppm	30 – 150	50 – 80	30 – 250
Mn ppm	30 – 500	110 – 145	30 – 700
Fe ppm	50 – 200	55 – 80	50 – 300
Cu ppm	5 – 15	4 – 7	5 – 65
* See the Fall 2015 issue of *From the Grove* magazine, www.californiaavocadogrowers.com/publications			
** Cl, although an essential plant nutrient, is very toxic to avocados and should be kept as low as possible; Na is not an essential plant nutrient and should be kept as low as possible.			
*** S, although an essential plant nutrient, is not included in FGL's standard tissue analysis.			

INTERPRETING A LEAF ANALYSIS

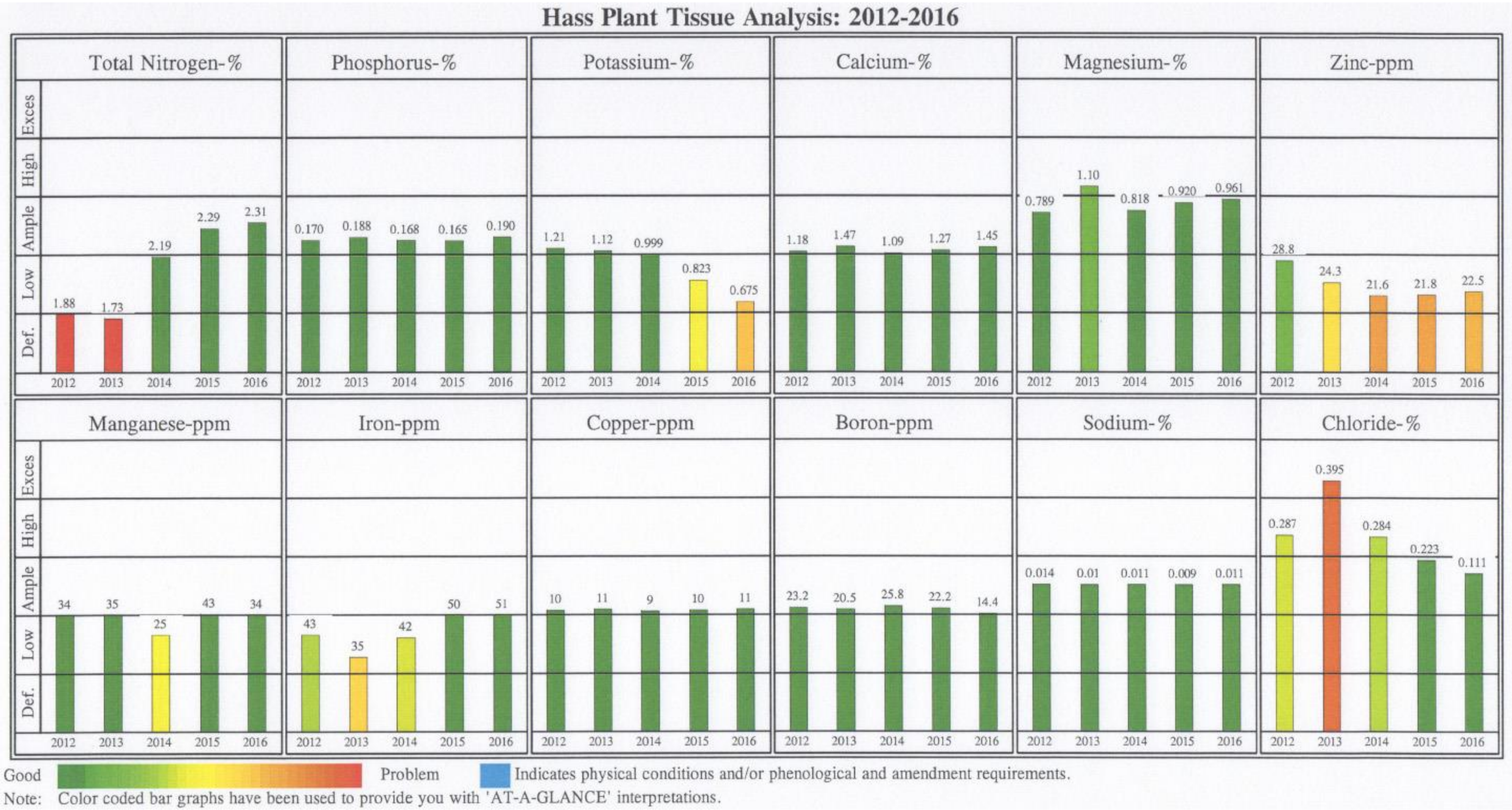
HASS PLANT TISSUE ANALYSIS

Test Description	Result	Units	Optimum Range
Macro Nutrients			
Total Nitrogen (Leaf)	2.31	%	2.2 - 2.4
Phosphorus (Leaf)	0.19	%	0.080 - 0.44
Potassium (Leaf)	0.675	%	1.0 - 3.0
Calcium (Leaf)	1.45	%	1.0 - 4.5
Magnesium (Leaf)	0.96	%	0.25 - 1.0
Micro Nutrients			
Zinc (Leaf)	22.5	ppm	30 - 250
Manganese (Leaf)	34	ppm	30 - 700
Iron (Leaf)	51	ppm	50 - 300
Copper (Leaf)	11	ppm	5.0 - 65
Boron (Leaf)	14.4	ppm	12 - 100
Sodium (Leaf)	0.011	%	0.0 - 0.25
Chloride (Leaf)	0.111	%	0.0 - 0.25
Nutrient Ratios			
Nitrogen:Potassium	3.42		1.7 - 2.2
Nitrogen:Phosphorus	12.2		11 - 23
Phosphorus:Zinc	84.4		20 - 50
Potassium:Magnesium	0.702		1.5 - 3.5
Nitrogen:Calcium	1.59		0.90 - 2.0

Graphical Results Presentation: Deficient | Low | Ample | High | Excessive

Good — Problem

LEAF ANALYSIS HISTORY



IRRIGATION WATER ANALYSIS

General Irrigation Suitability Analysis

Test Description	Result				Graphical Results Presentation				
Cations	mg/L	Meq/L	% Meq	Lbs/AF	Good	Possible Problem	Moderate Problem	Increasing Problem	Severe Problem
Calcium	264	13	52	720	**				
Magnesium	103	8.5	33	280	**				
Potassium	4	0.1	0	11	**				
Sodium	87	3.8	15	240					
Anions									
Carbonate	< 10	0	0	0					
Bicarbonate	420	6.9	28	1100	**				
Sulfate	635	13	54	1700	**				
Chloride	77	2.2	9	210					
Nitrate	145	2.3	9	390					
Nitrate Nitrogen	33			90					
Fluoride	0.5	0.026	0	1					
Minor Elements									
Boron	0.30			0.82					
Copper	< 0.01			0.00					
Iron	0.38			1.0					
Manganese	< 0.01			0.00					
Zinc	< 0.02			0.00					
TDS by Summation	1740			4700					
Other									
pH	7.3			units					
E. C.	2.08			dS/m					
SAR	1.2								
Crop Suitability									
No Amendments	Poor								
With Amendments	Poor								
Amendments									
Gypsum Requirement	0.0			Tons/AF					
Sulfuric Acid (98%)	24			oz/1000Gal	Or 58 oz/1000Gal of urea Sulfuric Acid (15/49).				
Leaching Requirement	17			%					

Test Description	Result		Graphical Results Presentation		
Chemical			Slight	Moderate	Severe
Manganese	< 0.01	mg/L			
Iron	0.38	mg/L			
TDS by Summation	1740	mg/L			
No Amendments					
pH	7.3	units			
Alkalinity (As CaCO3)	340	mg/L			
Total Hardness	1080	mg/L			
With Amendments					
Alkalinity (As CaCO3)	68	mg/L			
Total Hardness	68	mg/L			
pH	5.4 - 6.7	units			

- 1 acre-foot of water weighs ~2.7 million pounds
  - mg/L = ppm
  - ppm x 2.7 = lb/AF
  - 3 AF of water per year = 710 pounds of Na added to soil annually

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

- SAR = 3.8 /$\sqrt{(13+8.5)/2}$

- N @ 3 AF per year = 270 lb
- Cl @ 3 AF per year = 625 lb
- Ca @ 3 AF per year = 2150 lb
- Mg @ 3 AF per year = 850 lb

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Cations	mg/L	Meq/L	% Meq	Lbs/AF	Good	Possible Problem	Moderate Problem	Increasing Problem	Severe Problem
Calcium	264	13	52	720	**				
Magnesium	103	8.5	33	280	**				
Potassium	4	0.1	0	11	**				
Sodium	87	3.8	15	240					
Anions									
Carbonate	< 10	0	0	0					
Bicarbonate	420	6.9	28	1100	**				
Sulfate	635	13	54	1700	**				
Chloride	77	2.2	9	210					
Nitrate	145	2.3	9	390					
Nitrate Nitrogen	33			90					
Fluoride	0.5	0.026	0	1					
Minor Elements									
Boron	0.30			0.82					
Copper	< 0.01			0.00					
Iron	0.38			1.0					
Manganese	< 0.01			0.00					
Zinc	< 0.02			0.00					
TDS by Summation	1740			4700					
Other									
pH	7.3			units					
E. C.	2.08			dS/m					
SAR	1.2								
Crop Suitability									
No Amendments	Poor								
With Amendments	Poor								
Amendments									
Gypsum Requirement	0.0			Tons/AF					
Sulfuric Acid (98%)	24			oz/1000Gal	Or 58 oz/1000Gal of urea Sulfuric Acid (15/49).				
Leaching Requirement	17			%					

Test Description	Result		Graphical Results Presentation		
Chemical			Slight	Moderate	Severe
Manganese	< 0.01	mg/L			
Iron	0.38	mg/L			
TDS by Summation	1740	mg/L			
No Amendments					
pH	7.3	units			
Alkalinity (As CaCO3)	340	mg/L			
Total Hardness	1080	mg/L			
With Amendments					
Alkalinity (As CaCO3)	68	mg/L			
Total Hardness	68	mg/L			
pH	5.4 - 6.7	units			

- Leaching requirement is based on EC_w and the target EC_e

$$LR = EC_w / [(5 \times EC_e) - EC_w]$$

- Back calculating, an LR of 17% would allow for an $EC_e = 3.0$
- Avocado yield decline starts at $EC_e = 0.4$ dS/m
- This water would be toxic to avocados!!!

THANK YOU

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