Managing Orchard Salinity During and After Drought

December 9, 2015

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The Almond Conference

Speakers

Bob Curtis, Almond Board (Moderator)

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Understanding and Managing Salinity for Almonds

David Doll, UCCE Merced

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Understanding Salinity within Almond Orchards

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Salinity Tolerance of Almond

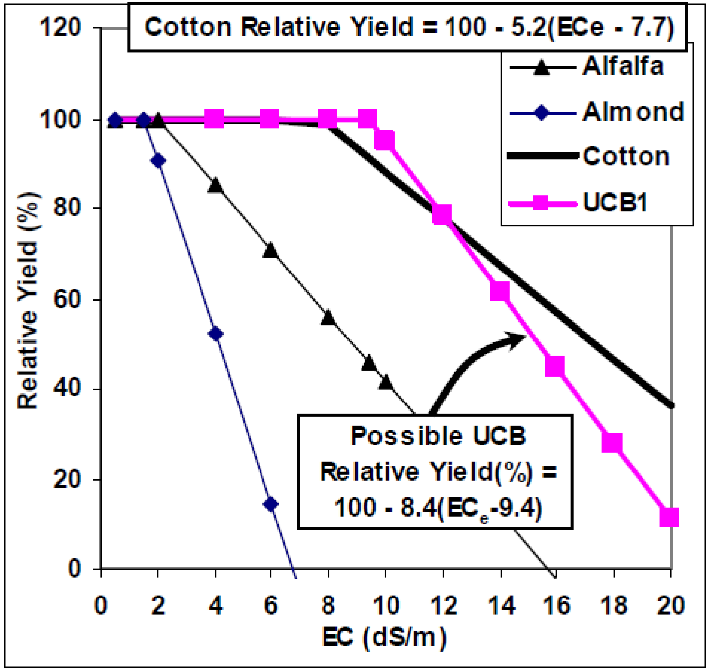


Fig. 2. Relative yield (RY) of various crops as a function of soil EC_e (Sanden, et al., 2004).

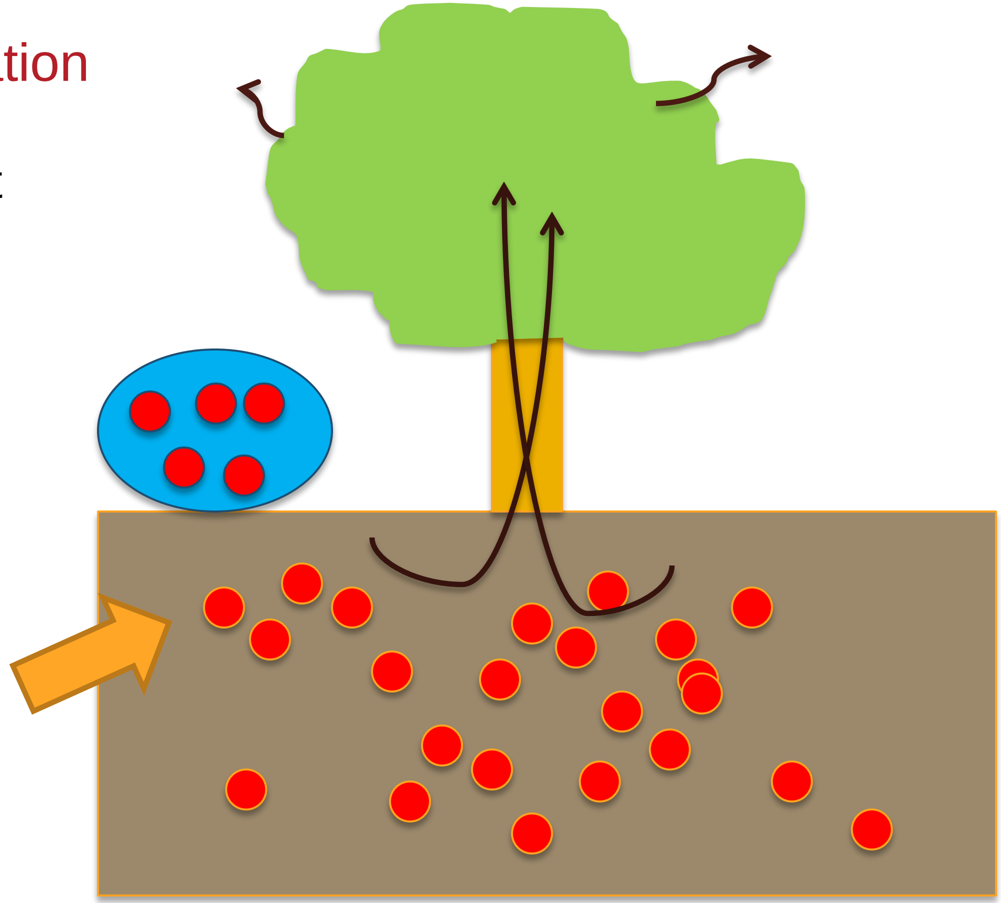
- How Tough are Almonds?
  - Sodium Sensitive
  - Every dS/m above 1.5 = 18-21 % growth rate decrease

	Degree of Growth/Yield Reduction			
Salinity of:	Unit	None	Increasing	Severe
Avg. root zone[1]	dS/m	< 1.5	1.5 – 4.8	> 4.8
Irrigation water[1]	dS/m	< 1.1	1.1 – 3.2	> 3.2

* Source: Adapted from E.V. Maas (1990), p. 280. Guidelines assume a 15 percent leaching fraction.

Salt Accumulation

- Why does salt accumulation occur?



Even good water can create salt issues!

Salt exclusion happens at the root.

Almond Salinity Issues: Plant Effects

	Degree of Restriction		
	None	Increasing	Severe
Sodium (%)	<0.25	.25-0.40	>0.40
Chloride (%)	<3.0	3.0-0.5	>0.5
Boron ppm	<30	30-85	>85

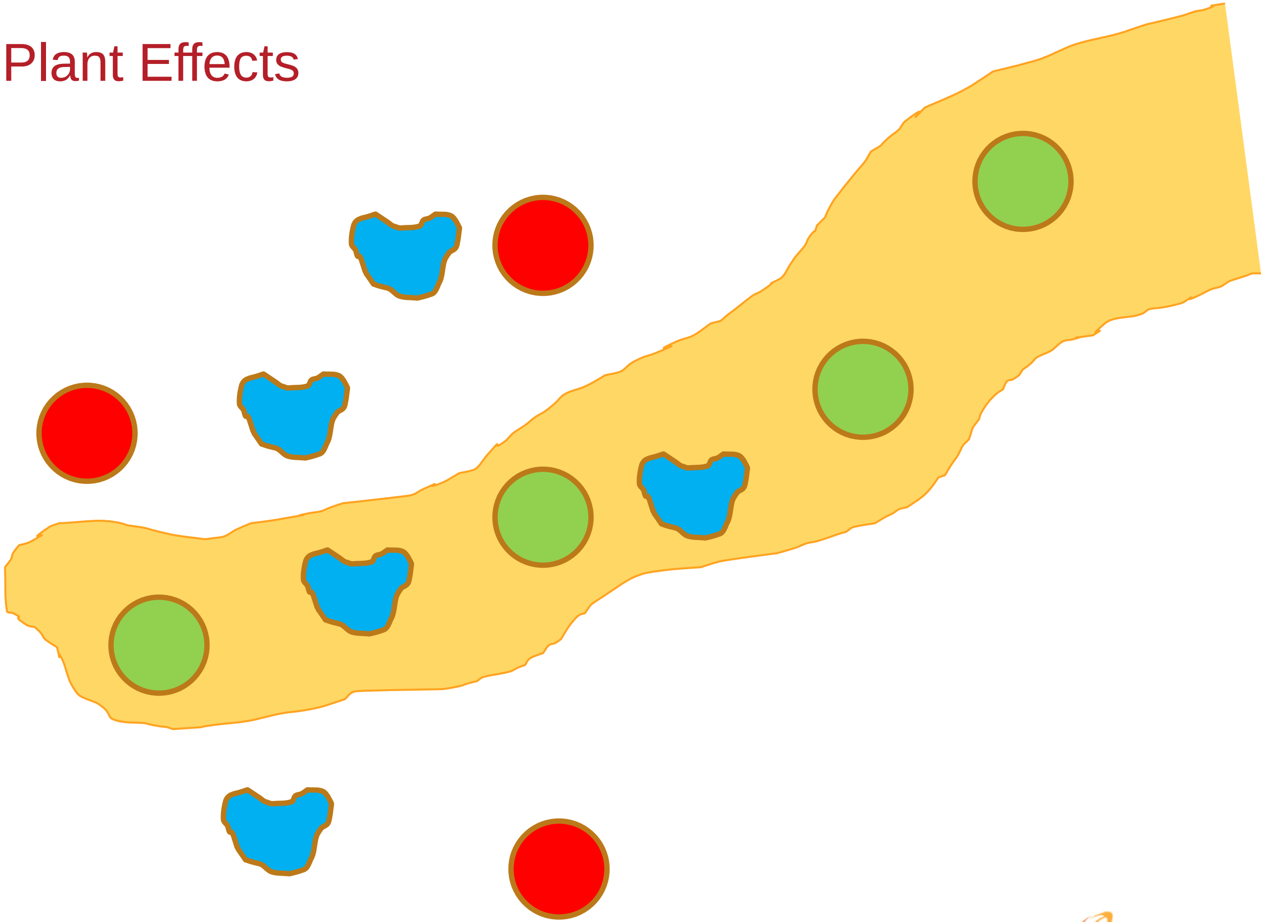
Almond Salinity Issues: Plant Effects

By the time you see toxicity::

- Trees are already experiencing osmotic effects prior to showing symptoms
- Can occur rapidly (especially with chloride)
- Takes 2-3 years of effective leaching to reduce tissue levels, regain productivity

Almond Salinity Issues: Plant Effects

Low Salinity:
Movement of Water from Osmotic Effects



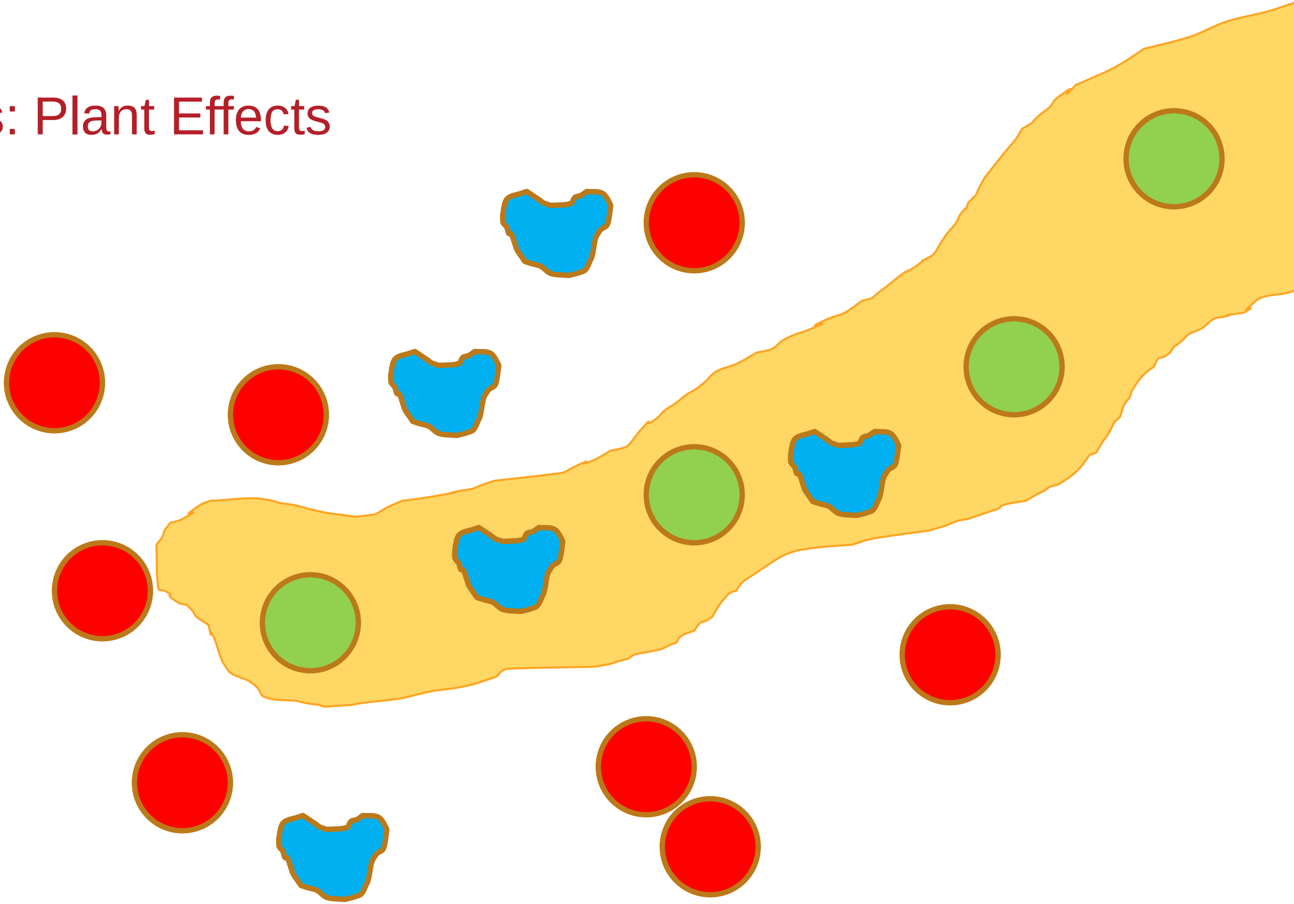
= Salt Cation

= Water Molecule

= Plant Compound

Almond Salinity Issues: Plant Effects

High Salinity:
Movement of Water from Osmotic Effects



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= Water Molecule

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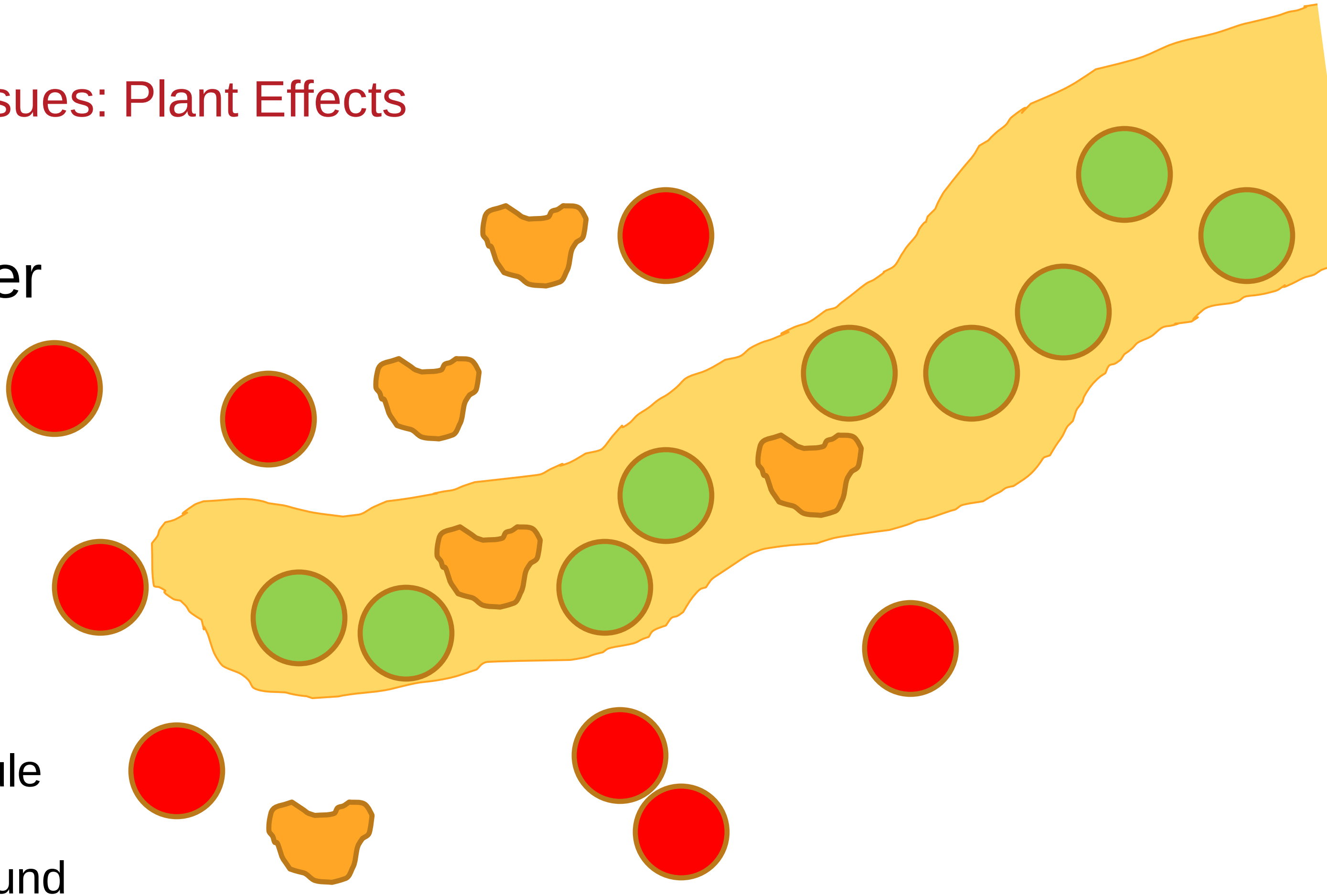
Almond Salinity Issues: Plant Effects

High Salinity:
Movement of Water from Osmotic Effects



= Salt Cation

= Water Molecule

= Plant Compound

Almond Salinity Issues: Plant Effects

Plant expends energy to create compounds to maintain osmotic gradient; reduces energy for crop

At some level, salt levels increase above the roots capacity to exclude-- uptake occurs

Salinity Tolerance of Almond

Sources of Salts in CA ag:

Present in soils

Fertilizer and composts

Irrigation water

- Surface – tends to be cleaner

- Well – variable quality

Water analysis needs to be conducted to know the quality of water!

Well Water Analysis: Interpretation

Sample	pH	Ecw (dS/m)	Ca (meq/L)	Mg	Na	HCO3 (meq/L)	SO4	Cl	SAR	SARadj	B (ppm)
High	7.79	2.88	10.10	14.4	12.0	4.71	26.8	4.55	3.43	8.13	0.77
UC	<7.0	<1.1			SAR			<4.0	<3.0		<0.5

Water is not ideal!

Salinity of:	Unit	None	Increasing	Severe
		Degree of Growth/Yield Reduction		
Avg. root zone[1]	dS/m	< 1.5	1.5 – 4.8	> 4.8
Irrigation water[1]	dS/m	< 1.1	1.1 – 3.2	> 3.2

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UC	<7.0	<1.1			SAR			<4.0	<3.0		<0.5

	Degree of Restriction None	Increasing	Severe
SAR	<3.0	3-9	>9.0
Chloride (meq/l)	<5	5-15	>15

Water is not ideal!

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

Well Water Analysis: Interpretation

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UC	<7.0	<1.1			SAR			<4.0	<3.0		<0.5

Acidifying water will drop adjusted SAR closer to reported SAR

Water is too hot!

pH dependent: Indicates that Ca2+ or Mg2+ will not remain free in soil solution

Well Water Analysis: Interpretation

Sample	pH	Ecw (dS/m)	Ca (meq/L)	Mg	Na	HCO3 (meq/L)	SO4	Cl	SAR	SARadj	B (ppm)
High	7.79	2.88	10.10	14.4	12.0	4.71	26.8	4.55	3.43	8.13	0.77
OK	7.89	1.20	4.33	3.5	6.42	1.77	10.1	0.99	3.25	5.44	0.46
UC	<7.0	<1.1			SAR			<4.0	<3.0		<0.5

Not the best water, but workable:

Adjust pH to free up calcium

Additional gypsum (500 lbs/acre foot = 2 meq Ca increase)

Well Water Analysis: Interpretation

Sample	pH	Ecw (dS/m)	Ca (meq/L)	Mg	Na	HCO3 (meq/L)	SO4	Cl	SAR	SARadj	B (ppm)
High	7.79	2.88	10.10	14.4	12.0	4.71	26.80	4.55	3.43	8.13	0.77
OK	7.89	1.20	4.33	3.5	6.42	1.77	10.1	0.99	3.25	5.44	0.46
???	7.66	0.86	1.91	2.9	4.48	6.3	0.36	1.69	2.91	6.74	2.6
UC	<7.0	<1.1			SAR			<4.0	<3.0		0.5

	Degree of Restriction		
	None	Increasing	Severe
Boron (mg/L)	<0.5	0.5-3.0	>3.0

Water Modification

- Lowering pH of Irrigation Water:
  - Titration for water must be performed to determine amounts needed.
  - Send water plus acid of choice to a local lab.
- Calcium Amendments
  - Vary;
  - Can be applied or injected

Water Modification

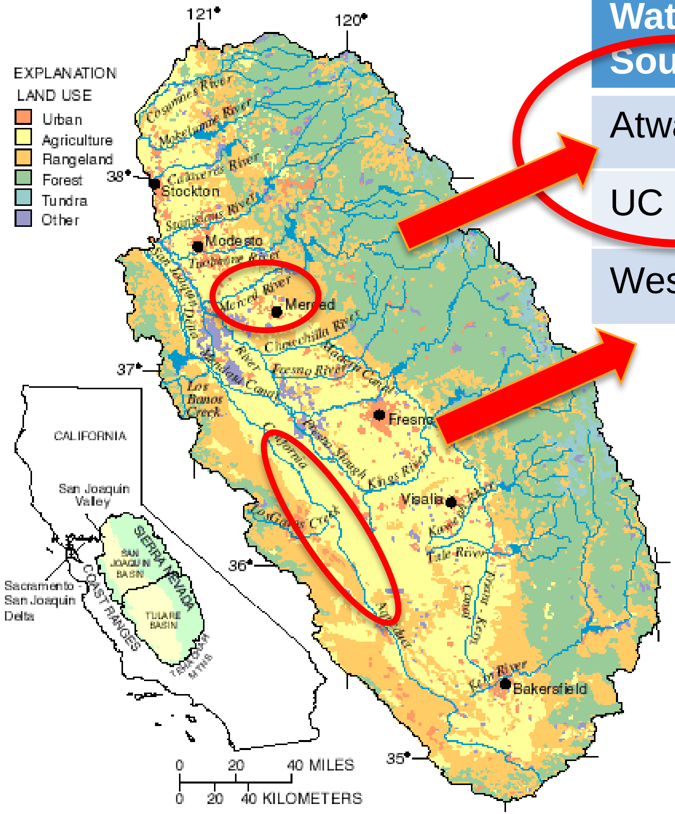
Salt	Formulation	Solubility (distilled water @20°C, at ph=7)		Soil Rxn and effect on pH
		(g/100 mls)	General rating	
Calcium nitrate	$Ca(NO_3)_2$	121	Highly soluble	Gradual, Neutral
Calcium chloride dihydrate	$CaCl_2 \cdot 2H_2O$	98	Highly soluble	Gradual, Neutral
Calcium chloride	CaCl2	74	Highly soluble	Gradual, Neutral
Calcium acetate	$C_4H_6CaO_4$	34.7	Highly soluble	Increase pH of acid soils
Gypsum	$CaSO_4 \cdot 2H_2O$	0.26	Moderately soluble	Gradual, Neutral
Dolomite	$CaMg(CO_3)_2$	0.03 (depends on soil ph)	Low solubility	Increase pH of acid soils
Lime	CaCO3	0.005 (depends on soil ph)	Very low solubility	Increase pH of acid soils
By-product ash	CaO or $Ca(OH)_2$	Variable (depends on soil pH)	Very low solubility	Increase pH of acid soils
Source: CRC Handbook of Chemistry and Physics, 56th Edition				

Water Modification

Adding Calcium to Water

- In solution: ~ 250 lbs of gypsum/acre ft to increase one meq/l of calcium
- Land grade applications made monthly – but need 6x more to get the same effect

Almond Salinity Issues: Soil Effects



Water Source	pH	EC dS/m	Sodium (meq/l)	Calcium (meq/l)	Mg (meq/l)	SAR/ adj SAR
Atwater	7.6	0.32	6.35	2.10	5.59	3.2/6.15
UC RECS		<1.1	<3.0			
Westside	8.3	1.24	7.6	3.5	0.7	5.2/11.1

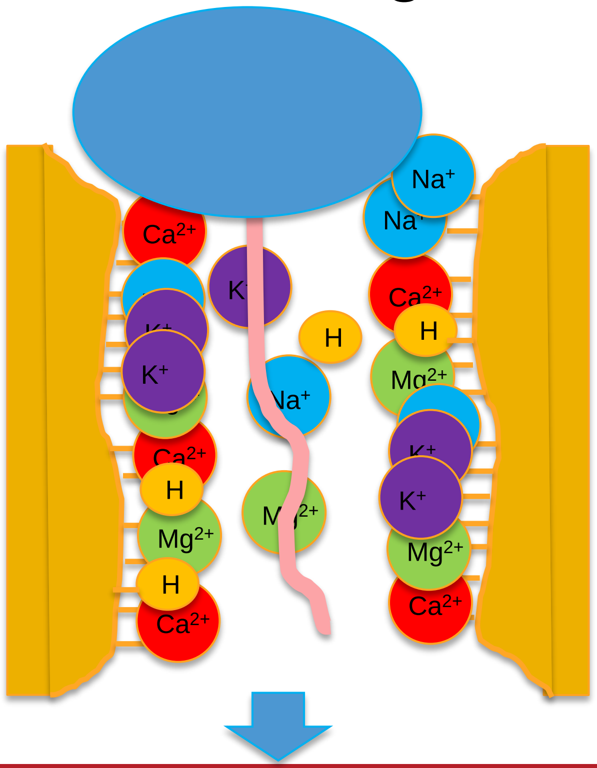
Almond Salinity Issues: Soil Effects

Low Exchange Capacity Soils will show sodium toxicity before high exchange capacity soils.

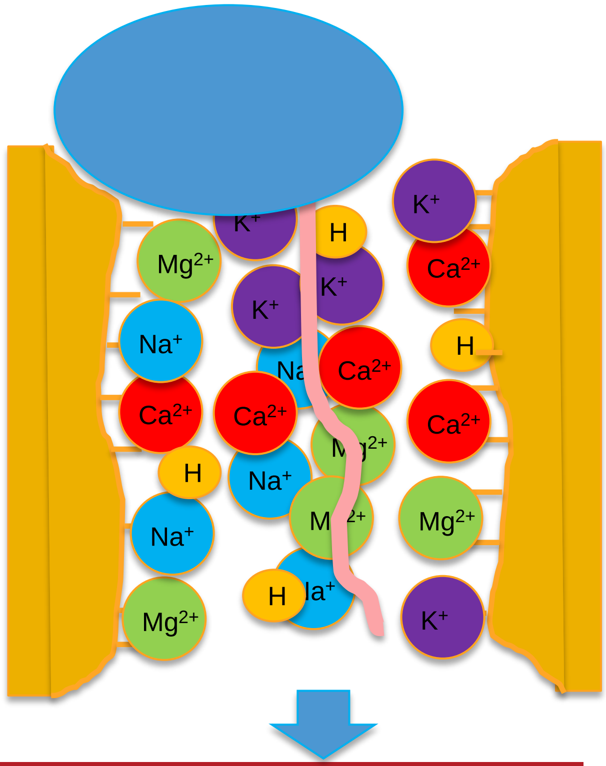
WHY?

Almond Salinity Issues: Soil Effects

Soil with high CEC



Soil with low CEC

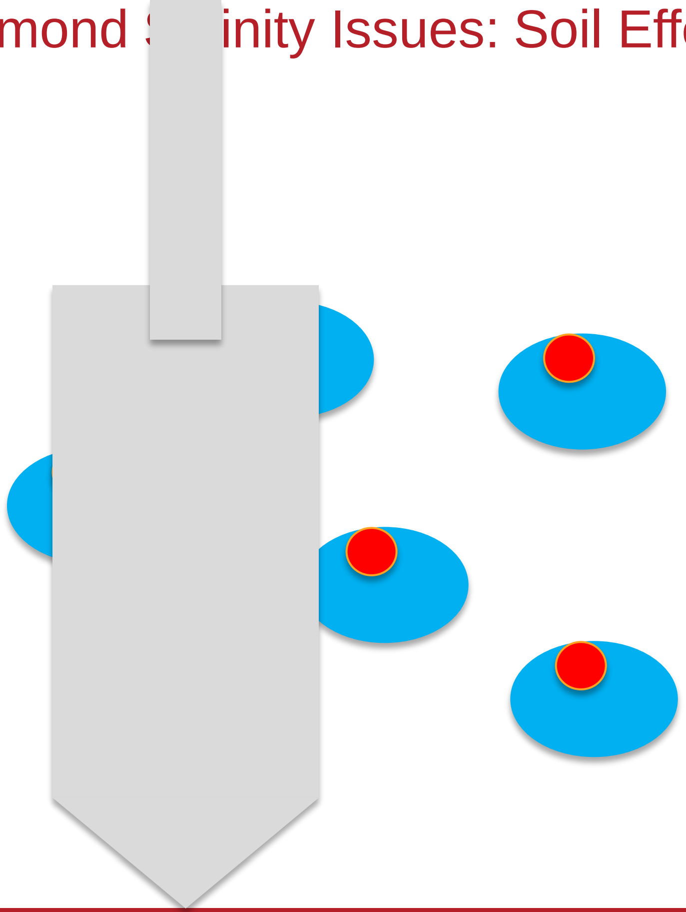


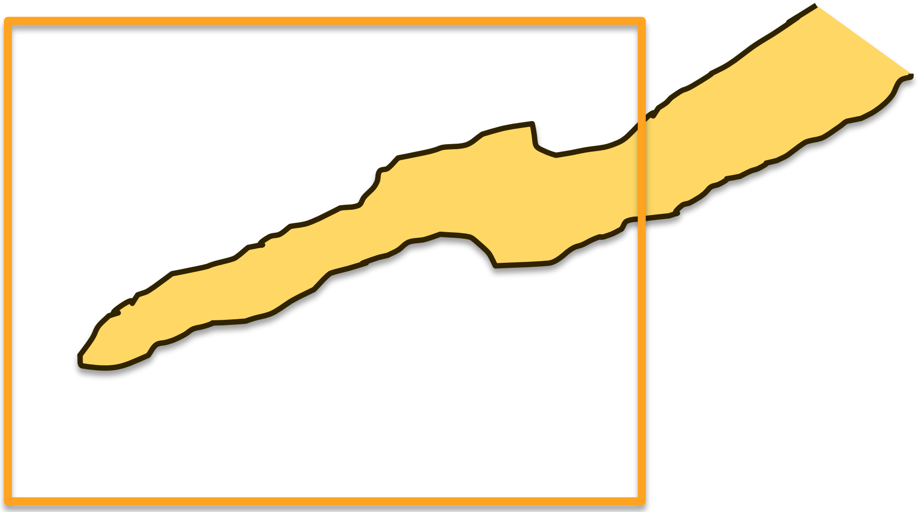
Almond Salinity Issues: Soil Effects

Soil Sampling may not provide answer in low CEC soils:

	E.C. (dS/m)	Sodium (meq/L)	Chloride (meq/L)
1’	0.19	0.55	0.31
2’	0.19	0.82	0.30
3’	0.81	3.12	0.94
4’	1.25	5.05	1.24
5’	0.93	3.96	0.93
UC Value	<1.5	<5.0	<5.0

Almond Salinity Issues: Soil Effects





Salinity that root is exposed to is not the same as volume sampled for LOW CEC SOILS

Managing Salinity within Almond Orchards

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Almond Salinity Issues: Soil Sampling

Soil Sampling should occur in the fall after the completion of the irrigation season

- Samples should be taken within the wetting profile;
- A complete soil profile should be pulled at even increments down to a minimum depth of five feet (e.g. 0”-12”, 13”-24”, 25”-36”, 37”-48”, and 49”-60”;
- Multiple locations can be pooled within a block, but each block/irrigation set should have an analysis;
- If struggling with infiltration, consider pulling a 0-6” sample to look for chemical imbalances;
- If average root system salinity is over 1.5 dS/m, than a leaching program should be considered;
- Follow up the leaching program with another round of sampling to determine the effectiveness of the program.

4 Utilized Principles:

- Managing Salt Build-up → In-Season Leaching Fractions
- Displacement of Salts → Water Amendments
- Leaching of Salts → Dormant Leaching
- Rootstock Resistance → Pre-plant decision

Almond Salinity Management: In-Season Leaching

- Dependent upon the salinity of the soil and water applied.
- Requires salinity analysis of soil and water

ECe = Salinity of the Soil (dS/m)

ECiw = Salinity of Irrigation Water (dS/m)

Ea = irrigation system application efficiency

$$\text{Leaching Requirement (LR)} = \frac{ECiw}{(5 \times ECe) - ECiw}$$

$$\text{Gross Inches} = \frac{\text{Net Inches Required}}{(1 - LR)\ (Ea)}$$

Almond Salinity Management: In-Season Leaching

- Example: 2.33 net inches of water needed, Ea=80%

ECe = Salinity of the Soil (dS/m) = 4.0

ECiw = Salinity of Irrigation Water (dS/m) = 2

$$\text{Leaching Requirement (LR)} = \frac{\text{ECiw}}{(5 \times \text{ECe}) - \text{ECiw}} = \frac{2}{(5 \times 4.0) - 2} = 0.11$$

$$\text{Gross Inches} = \frac{\text{Net Inches Required}}{(1 - \text{LR})(\text{Ea})} = \frac{2.33}{(1 - 0.11)(0.8)} = 3.69$$

Almond Salinity Management: In-Season Leaching

Generalized LC:

- If want soil EC (ECe) = water EC (ECw)= 33%
- ECe = 2X ECw, LF = 10%
- ECe = 3X ECw, LF = 5%

Almond Salinity Management: In-Season Leaching

Risks of in-season leaching programs:

- Too wet of soils for proper root development
  - Encourages root disease
- May encourage vigor, increased timing of fruit development, risk of hull-rot;
- May leach nitrate;
- Dry down will pull salts back into the rootzone (e.g. hull-split RDI or harvest).

Is this the best strategy?

Almond Salinity Management: Dormant Leaching

Leaching is the primary step to manage salts but it is not necessary every irrigation or perhaps even every season, only when crop tolerances are approached

Leaching is most efficient in the winter when crops are dormant and ET is low. Timing does not coincide with critical periods of nitrogen fertilization and plant activity, reducing leaching risk and disease;

Almond Salinity Management: Dormant Leaching

- The soil water content must exceed field capacity in the root zone for leaching to occur;
- Intermittent periods of irrigation and rainfall will more efficiently leach salts and boron than continuous,
- During rain events, drip systems, or limited pattern microsprinklers should be ran to help keep salts out of rootzone
- Low CEC soils (sands, loamy sands) will require less water than higher CEC soils due to reduced salt concentration/cation “tie up”

Almond Salinity Management: Dormant Leaching

	Proportion that rootzone salinity exceeds threshold					
	1.0X	1.3X	2X	2.6X	3.3X	4X
Peach (dS/m)	1.5	1.95	3	3.9	4.95	6
PxA Hybrid (dS/m)	2	2.6	4	5.2	6.6	8
Inches of water/Foot	0	0.6	1.8	3	4.2	5.4

Assumes that rootzone is at field capacity

Almond Salinity Management: Dormant Leaching

Dormant leaching programs for sodium will most likely reduce chloride and boron

- Managing chloride is easier due to being an anion, and less water will be needed;
- If managing boron (weak anion/neutral), more water will be needed than chloride (about twice the amount);
- Amounts will vary based on soil and chloride load, but would start with about ½ the amount required for sodium

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Almond Salinity Management: Displacement

Increasing cation concentrations can help to displace sodium;

- Use of calcium or magnesium containing amendments;
  - Generally rely on calcium as it has other plant benefits;
  - Some sources may precipitate with water source.
- Acidifying the soil to decrease soil pH, increasing hydrogen ions;
- Not needed for chloride;
- May not be as useful for low CEC soils.

Almond Salinity Management: Overview

Low CEC Soils (< 12 meq/100 g)		Higher CEC Soils (> 12 meq/100 g)
Sand, Loamy sands	**Texture**	Sandy loams, loams, silts, and clays
0.4”-1.5” per foot	**Water Holding Capacity**	>1.5” per foot
High	**Severity of Uptake Burn**	Increases with salinity
Low	**Difficulty to Leach**	High due to WHC, CEC
2-4 times the WHC, (8”- 15”)	**Leaching Amounts**	3”-15” plus profile fill (~10-22”)
Low rates	**Amendments**	High Rates (CEC)

Almond Salinity Management: Rootstock Selection

Trial was established in 1989 on a sandy soil with low exchange capacity (3.1 meq/100g of soil)

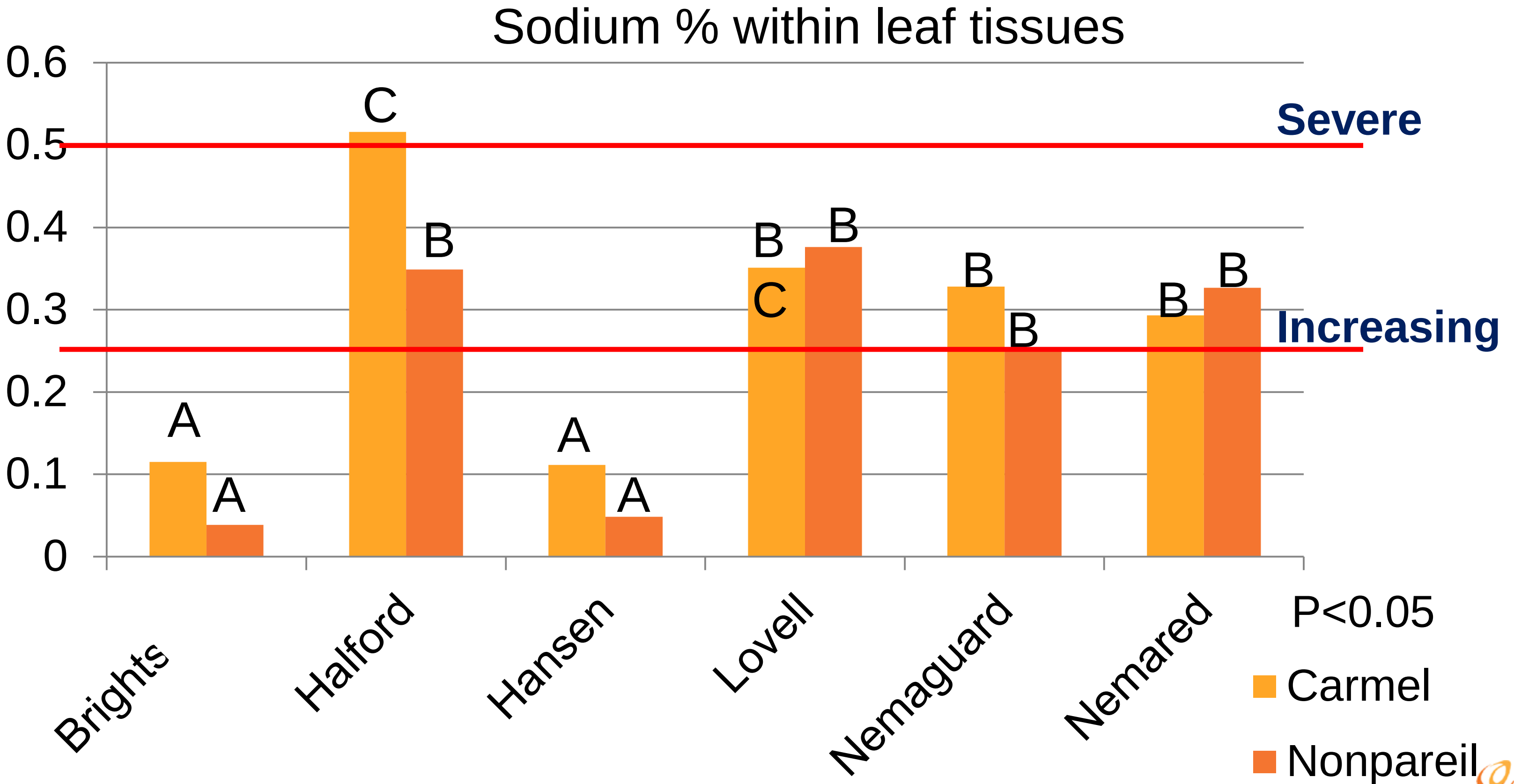
- Irrigated with solid set sprinklers with low quality groundwater
  - moderately high sodium, 6.35 meq/L (SAR= 3.06)
  - low chloride 0.75 meq/
- 6 Rootstocks: Brights Hybrid, Halford, Hansen, Lovell, Nemaguard, Nemared,
- 5 blocks of 5 trees established in RCBD planted 24’x24’

Almond Salinity Management: Rootstock Selection

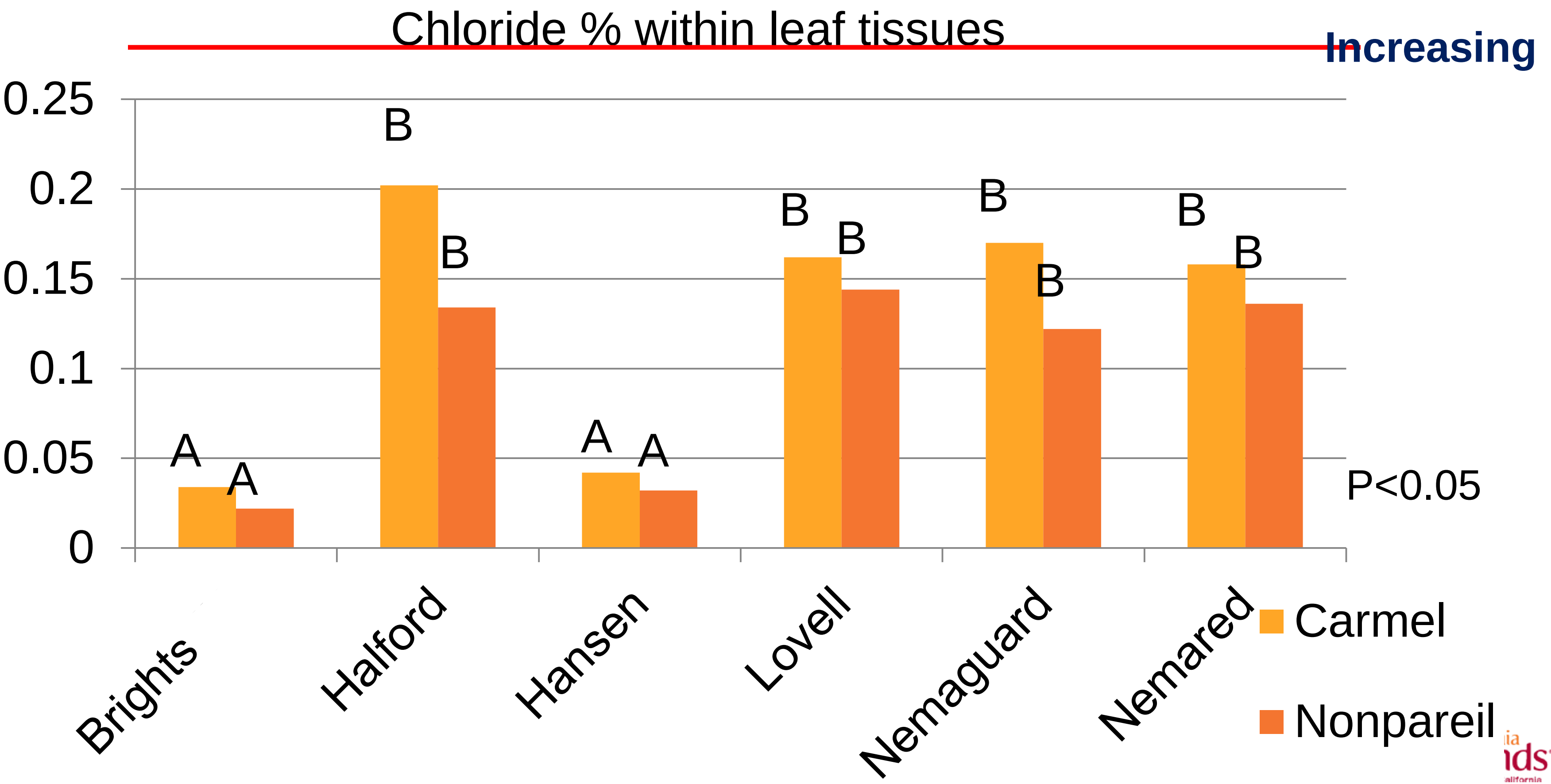
Around the orchards 10th year, marginal leaf scorching started to appear on peach rootstocks

Possible differences in salt tolerance?

Almond Salinity Management: Rootstock Selection



Almond Salinity Management: Rootstock Selection



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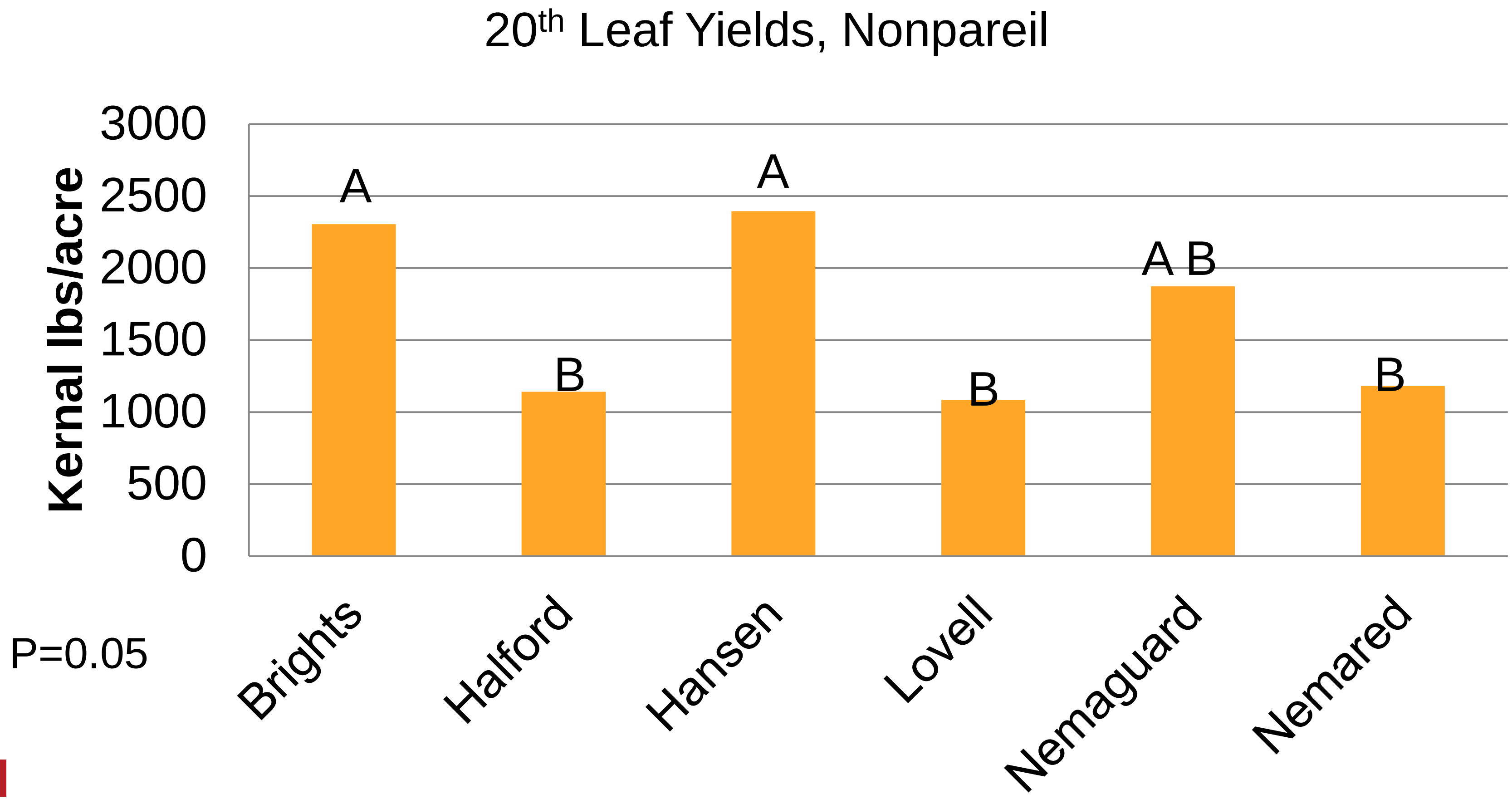
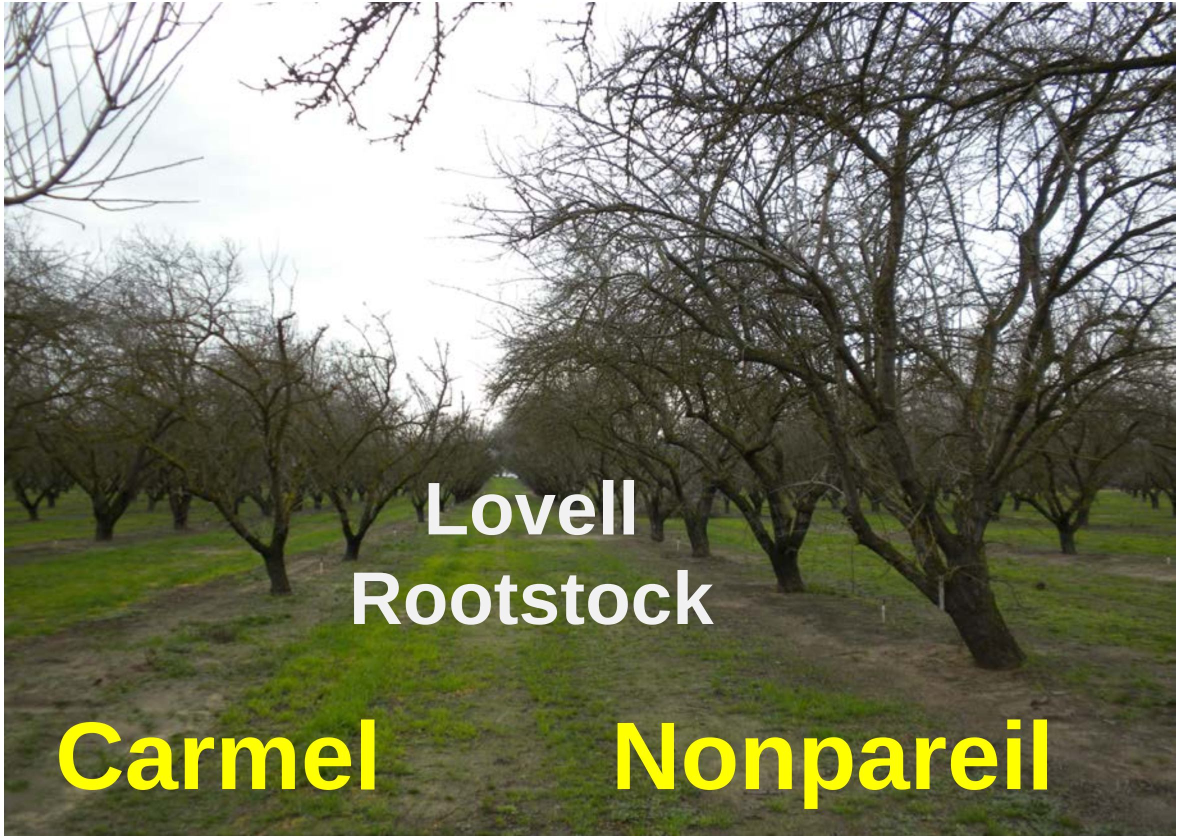
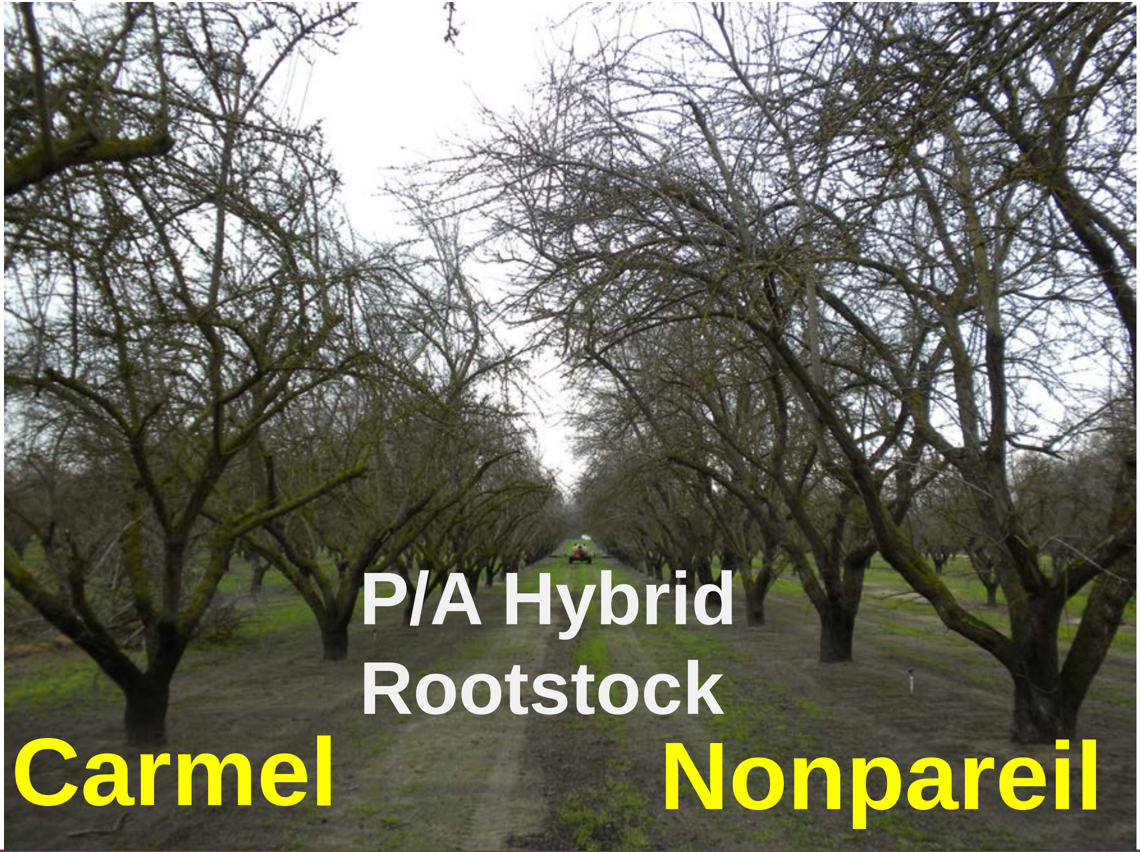


Almond Salinity Management: Rootstock Selection



Almond Salinity Management: Rootstock Selection



Almond Salinity Management: Rootstock Selection

Rootstock selection does impact salinity tolerance with P/A hybrids appearing more tolerant to SODIUM/CHLORIDE than peach rootstocks.

Relative Salt Tolerance of 15 Almond Rootstocks

	% Sodium	% Chloride
Nemaguard	0.99	0.51
Lovell	0.70	0.50
Guardian	0.76	0.41
Cadaman	0.38	0.25
Empyrean 1	0.09	0.07
Hansen	0.09	0.07
Nickels	0.28	0.15
GF 677	0.04	0.05
Cornerstone	0.04	0.05
Viking	0.29	0.21
Atlas	0.94	0.29
Krymsk 86	0.60	0.32
Penta	0.30	0.41
Julior	0.35	0.16
Empyrean 101	0.06	0.04

Roger Duncan, UCCE Stanislaus

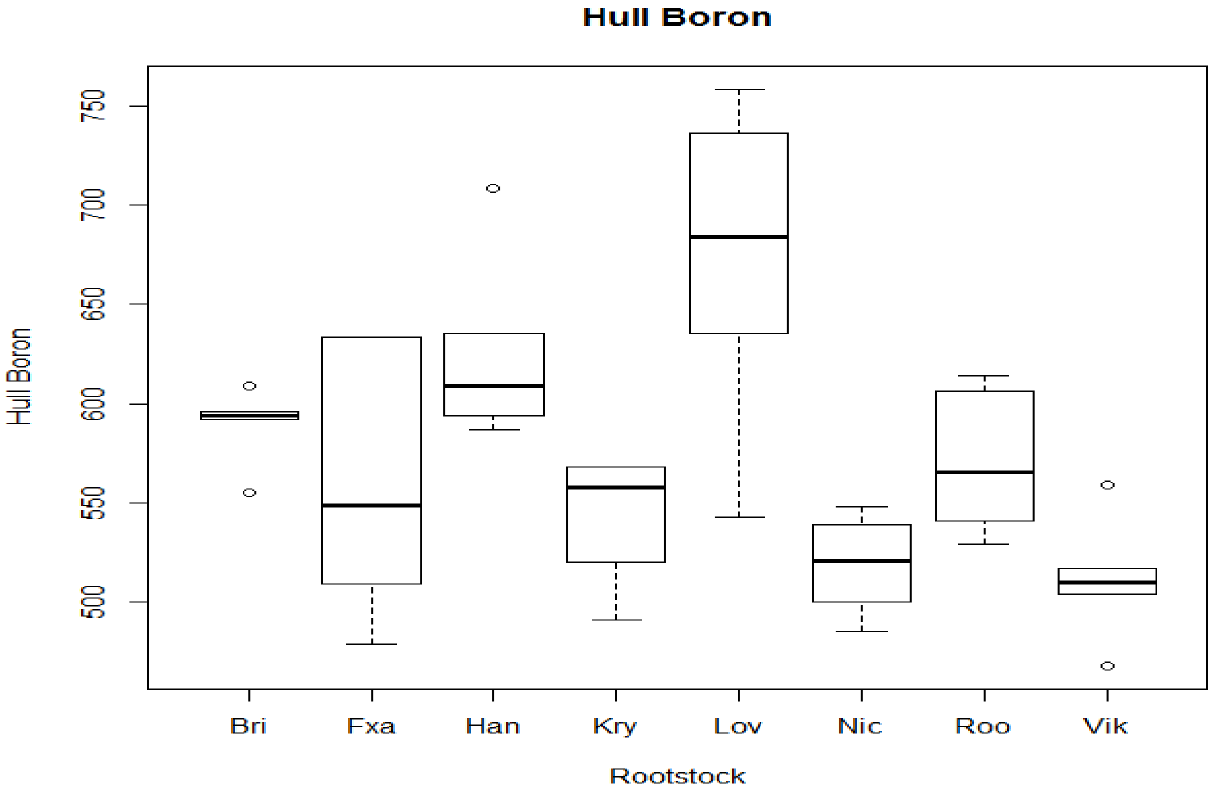
Almond Salinity Management: Rootstock Selection

Yolo County Rootstock Trial (Debuse, Pope)

Methods: 'Nonpareil' nursery grafted trees on eight rootstocks were planted Feb, 2011, at 22' x 18'. Twenty Titan SG1s were added April, 2011, but not in the replicated trial.

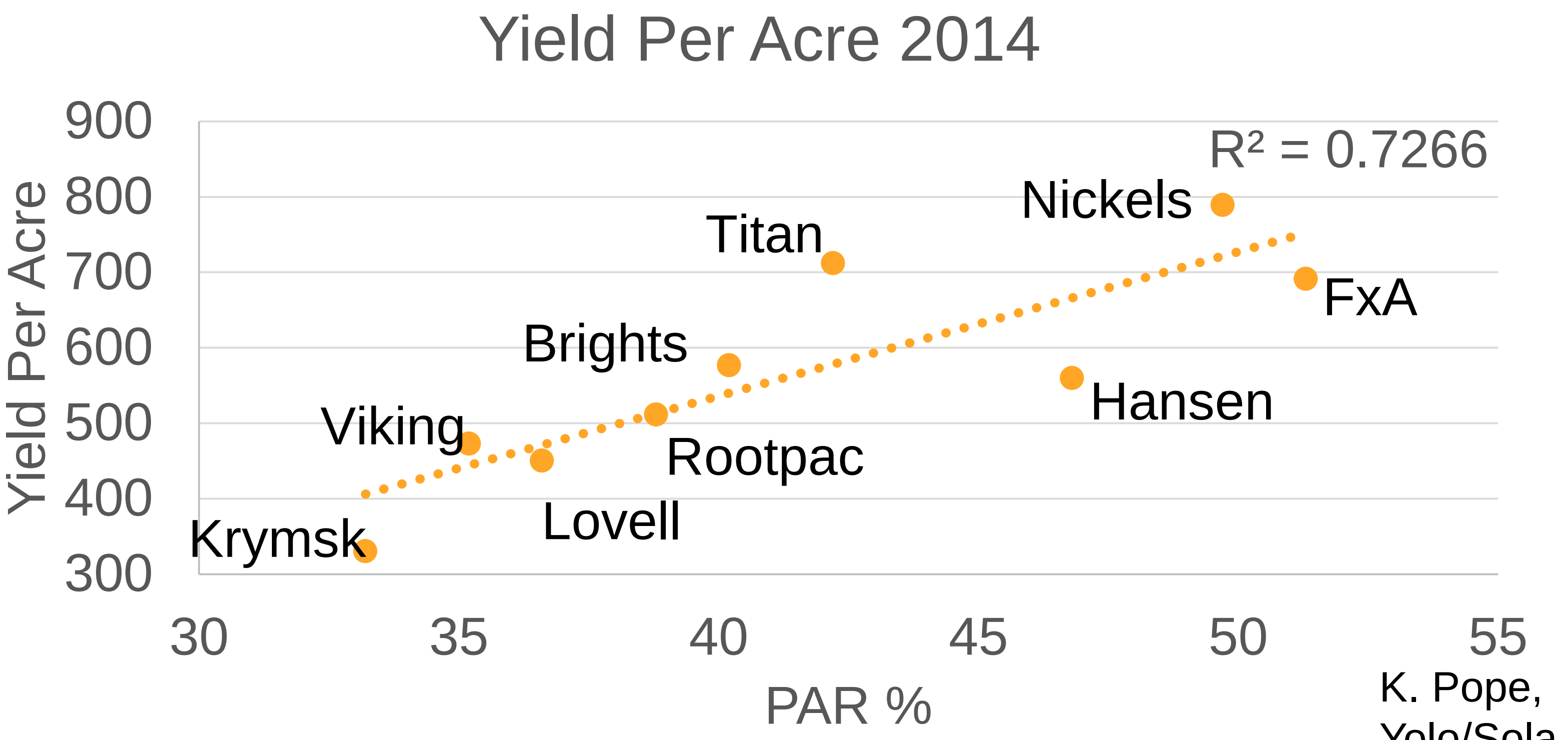
The trial is located in Yolo County north of Cache Creek. The soil is Marvin silty clay loam. Boron in the irrigation water ranges from <1mg/l to 3.1 mg/l, depending on year and month.

Almond Salinity Management: Rootstock Selection



K. Pope, UCCE Yolo/Solano

Almond Salinity Management: Rootstock Selection



K. Pope, UCCE Yolo/Solano

Almond Salinity Management: Variety Influence

	Na (%)	Cl (%)	K (%)	Al (ppm)	Mn (ppm)	Zn (ppm)
Nonpareil	0.18	0.55	1.50	168	78	29
Fritz	1.11	0.75	0.57	294	206	67
Threshold (July)	<0.25	<0.3	> 1.4	??	20	15

Roger Duncan, UCCE Stanislaus

Almond Salinity Management

- Spend some time to improve distribution uniformity in orchard
- Be careful with too salty of water – may do more harm than good!
- Know your water, soil, and utilize a leaching program
- Monitor tissue levels consistently

Quick Notes on DU Improvement

- Micro-irrigation systems decline in DU as they age (most dramatically after 5 years);
- Clean or remove hose screens, flush lines monthly, replace emitters with the same emitter;
- Use amendments that won’t precipitate – dependent upon water quality;
- Check pressures and flows at the emitter, risers, and pump.

These practices help reduce the impacts of salinity!