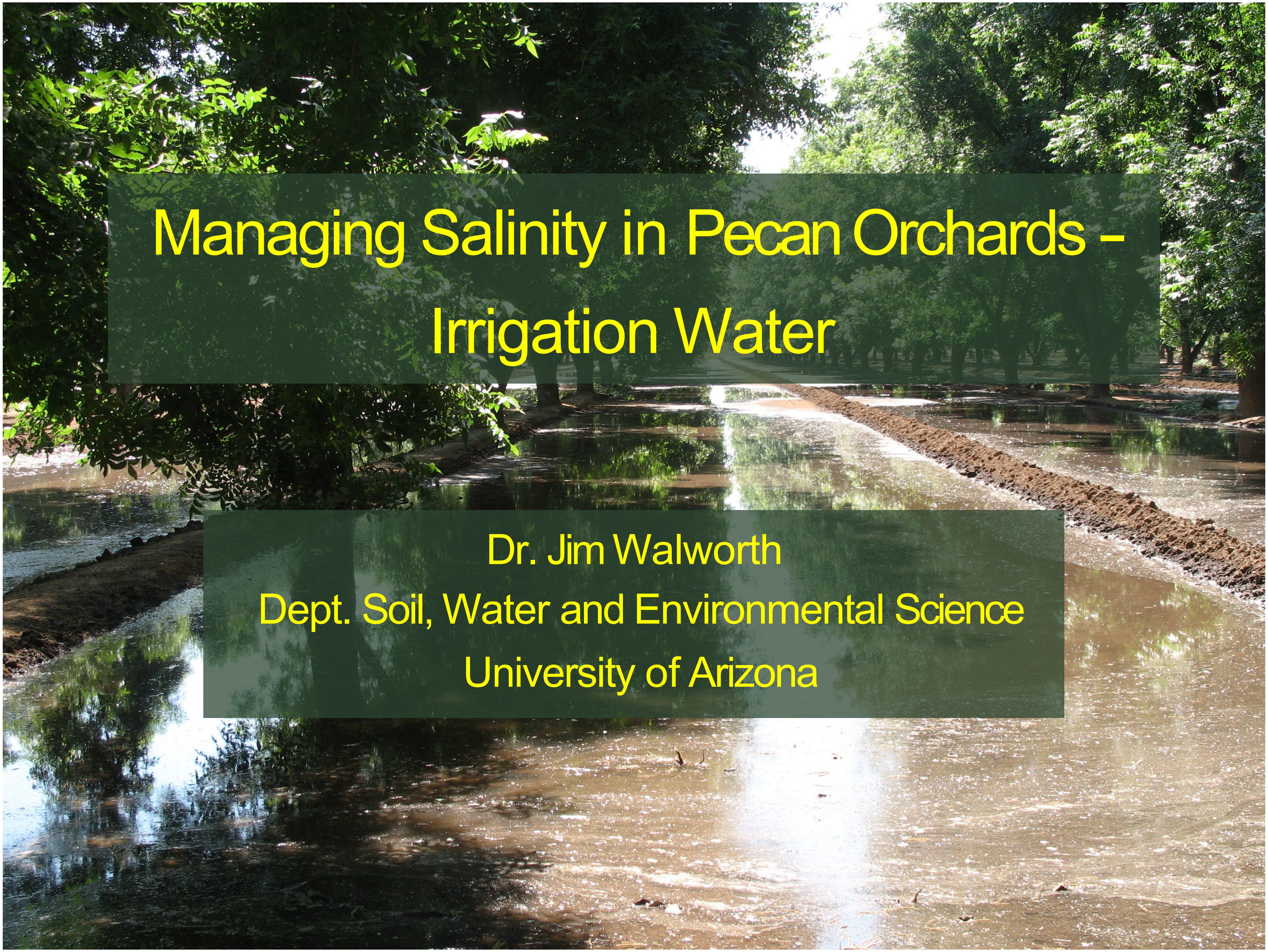

Managing Salinity in Pecan Orchards – Irrigation Water

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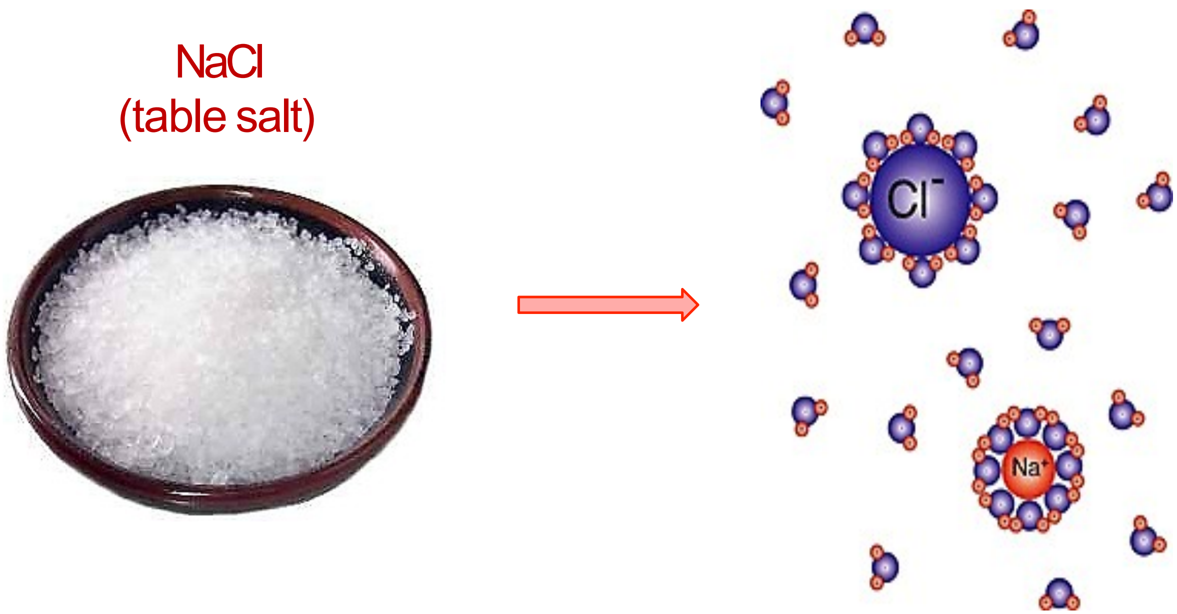
Symptoms of salt damage in pecans include marginal leaf necrosis, eventual necrosis of entire leaves and tree defoliation

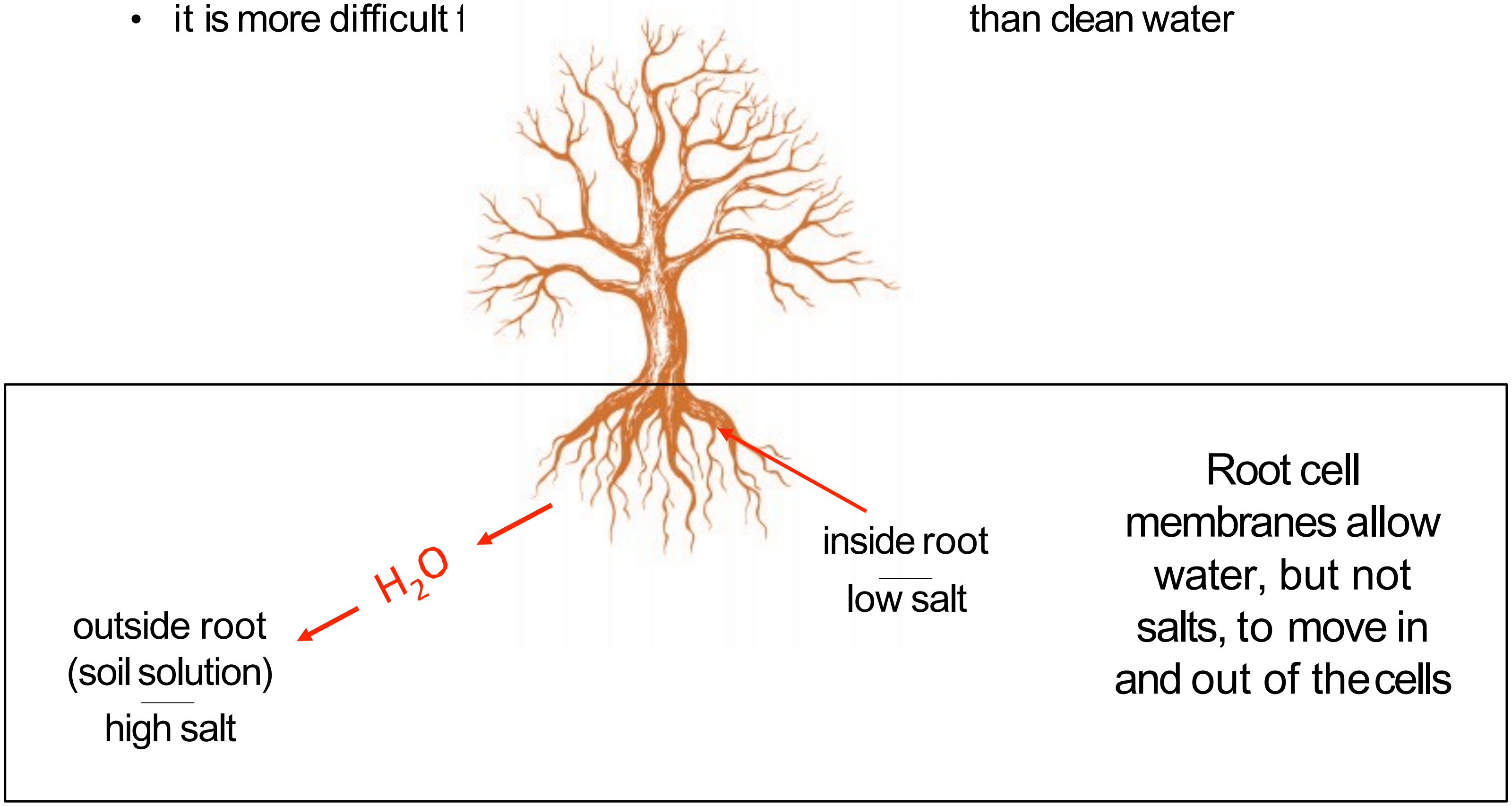
Dissolved salt molecules artifact water molecules

- Water molecules cluster around salt molecules
- This restricts the ability of the water molecules to move around freely
  - It lowers the water's *osmotic potential* and *biological availability*
- Salts make soil water less available to plants



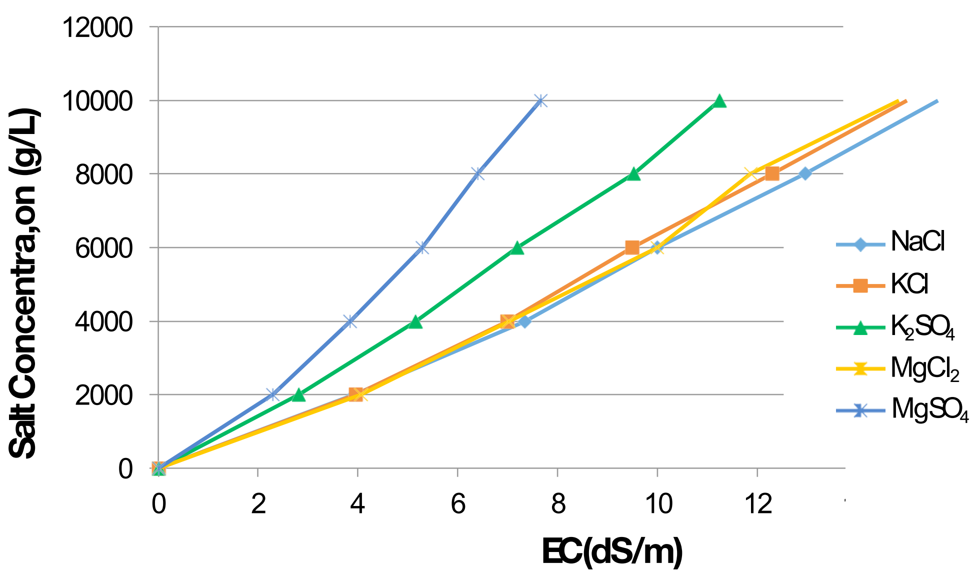
Effect of Salts on Plants

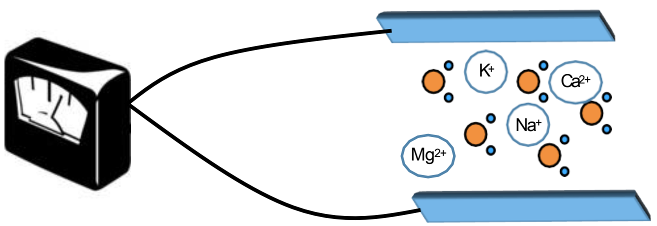
- Water is drawn *away from regions of low salt* concentration (inside the root) and *towards regions of high salt* concentration (outside the root)
  - To absorb water, t[…]lt gradient
  - it is more difficult t[…] than clean water

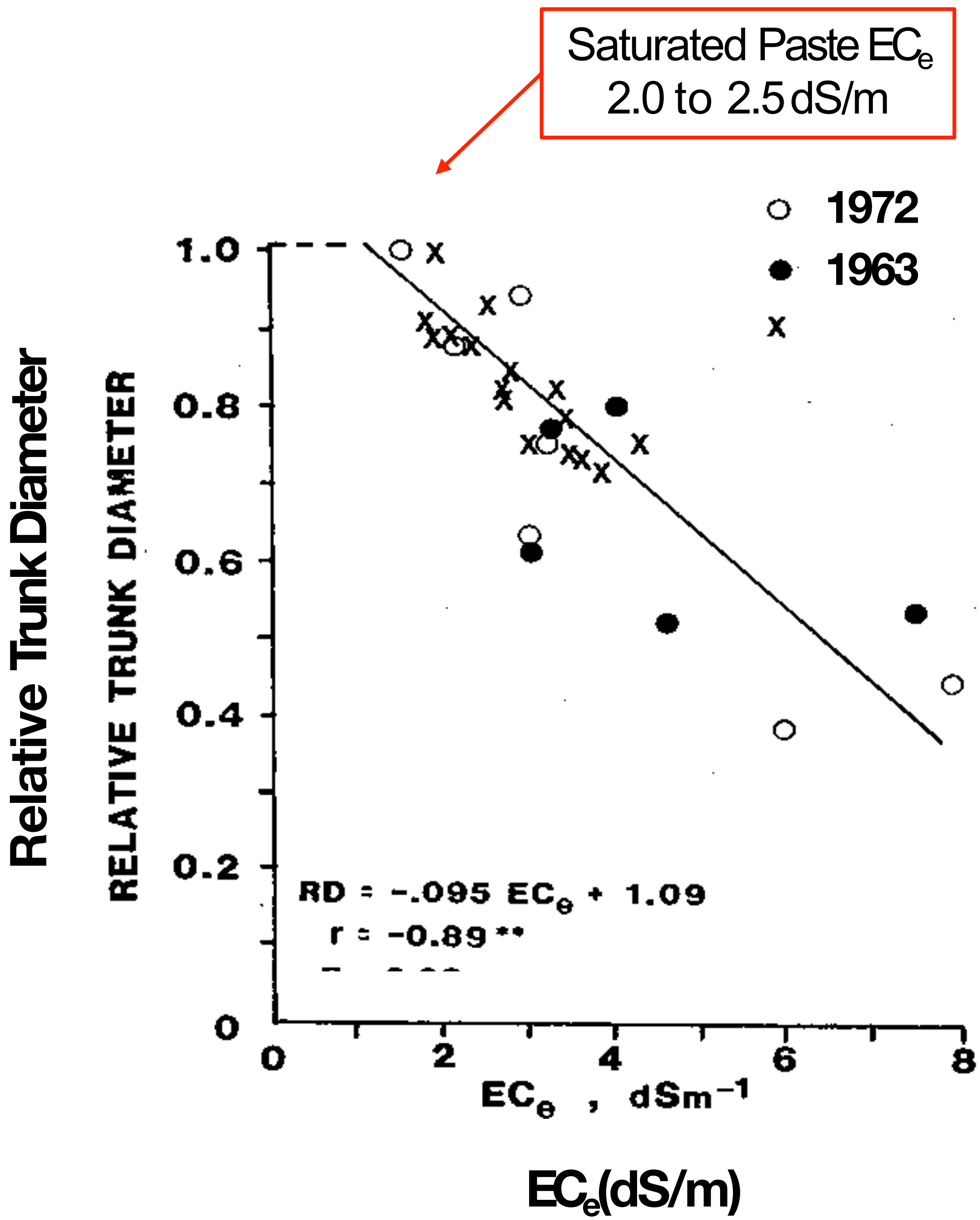


Measuring Salinity: Electrical Conductivity

- Salt ions dissolved in water conduct electricity
- The total amount of soluble soil salts is estimated by measuring the electrical conductivity (EC) of water
  - EC is measured in units of conductance over a given distance
    - deci–Siemens per meter (dS/m)
    - older units are mmhos/cm, identical to dS/m
    - conversion: EC x 640 ≈ ppm *or* mg/kg *or* mg/L



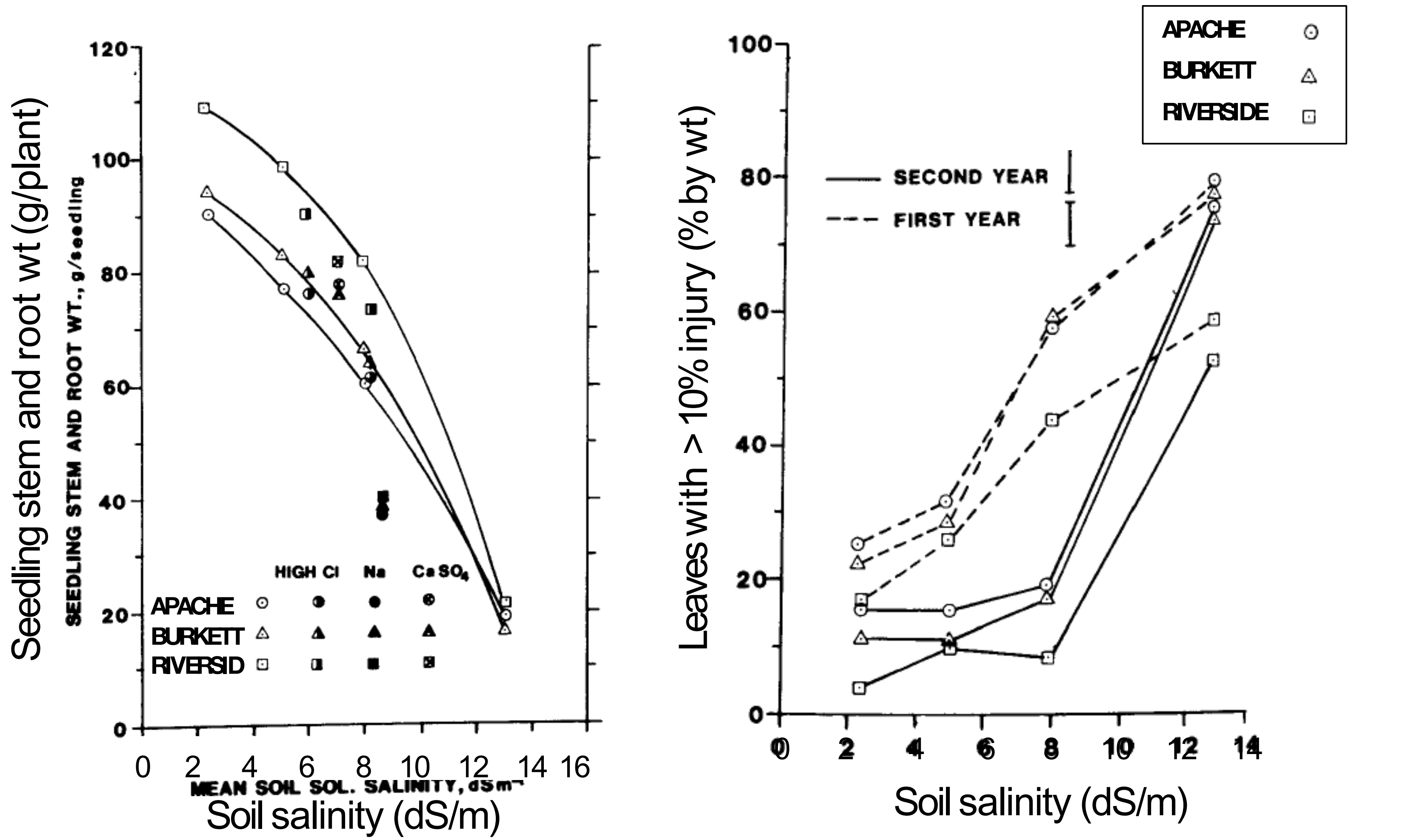




How much soil salinity is too much for pecans?

Miyamoto et al., 1986

Salinity tolerance varies among pecan cultivars, but we lack data for most cultivars



Miyamoto et al., 1985

Irrigation water is the major source of salts in most irrigated soils

Annual salt addition

Salt in irrigation water (ppm)	Salt added to orchard (tons/ac)
200	1.1
400	2.2
600	3.2
800	4.3
1000	5.4
1200	6.5
1400	7.6
1600	8.6
2000	10.8

Assumes 4 acre–feet of water per year

Irrigation Water Salinity Guidelines for Pecans

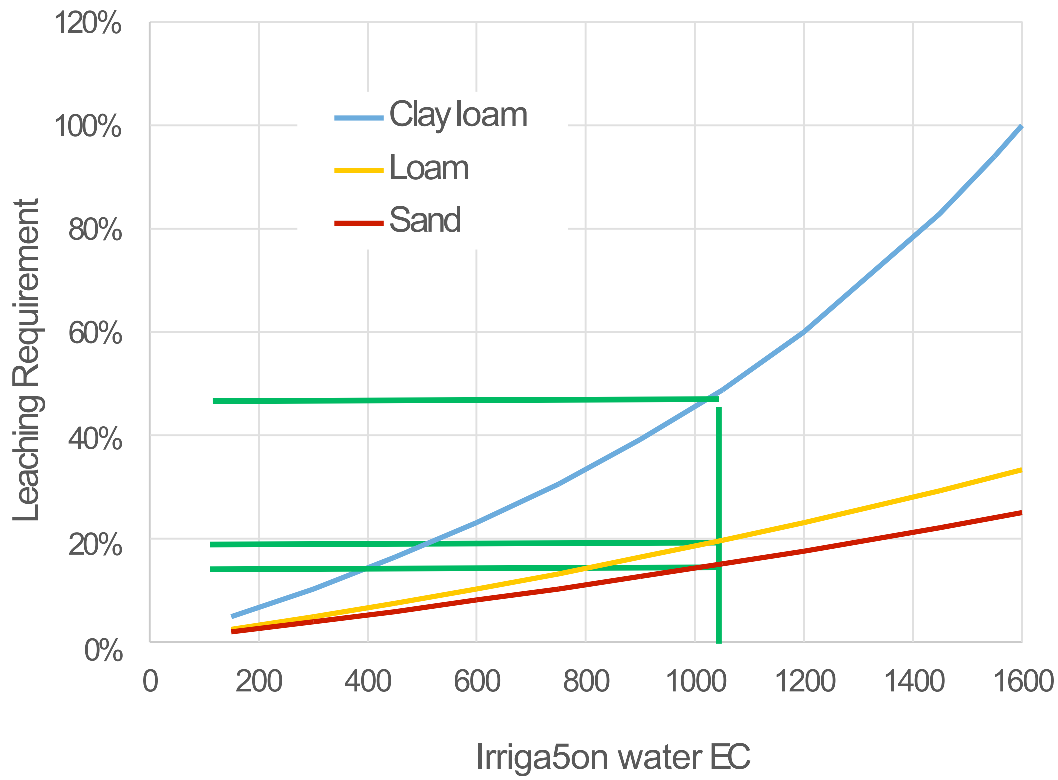
Soil Texture	Salinity limit	
	EC(dS/m)	mg/L (ppm)
Clay, clay loam	< 1.0	< 640
Loam	1.0 – 2.0	640 -1280
Sand, loamy sand	2.0 – 2.5	1280 -1600

Salinity tolerance is lower in clayey soils than in sandier soils because it is more difficult to leach salts from clay soils

Leaching to Maintain Low Soil Salts

The leaching requirement (LR) is the excess water (beyond tree needs) that must be applied to keep salts at a level that will not reduce yield

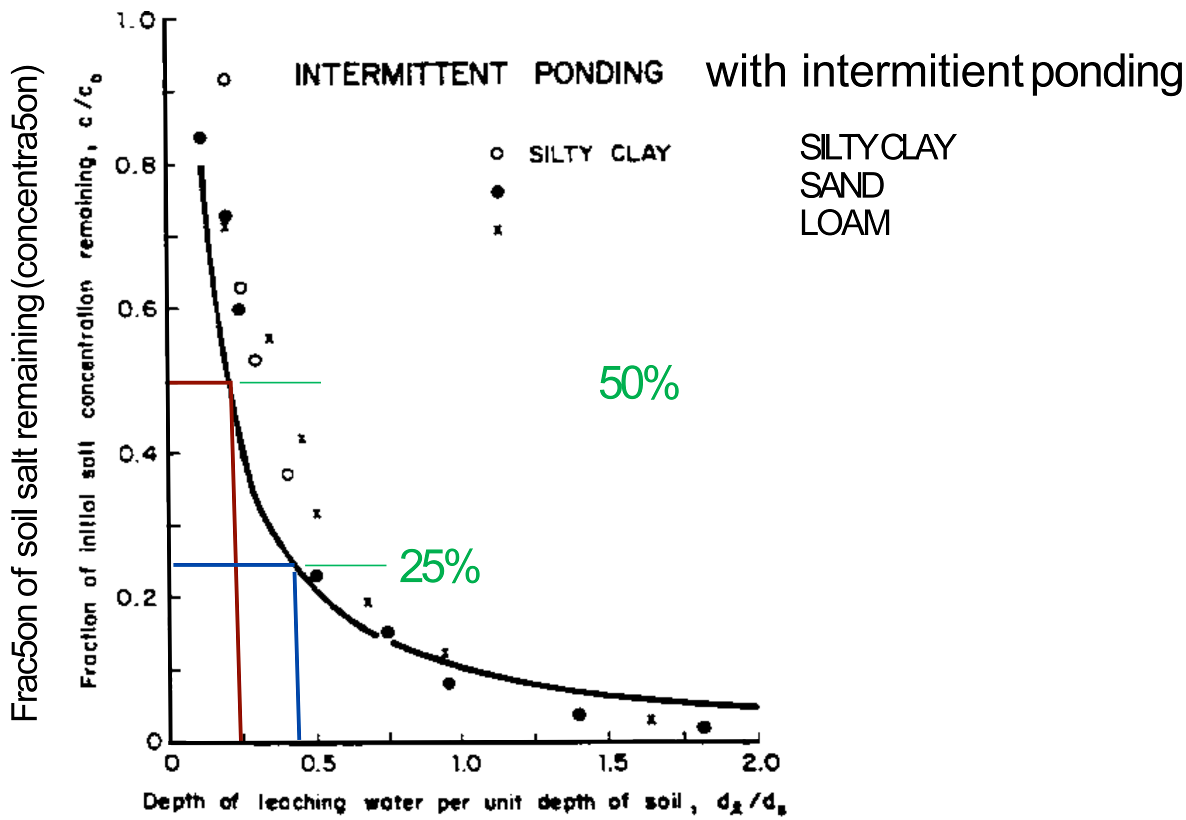
- LR increases as irriga5on water salinity increases
- LR increases as soil clay content increases



LR for 1000 ppm water

Soil texture	LR
clay, clay loam	45%
loam	19 – 45%
sand, loamy sand	14 – 19%

Leaching Required to Reclaim Saline Soil



Depth of leaching water per depth of soil (n H_2O/n soil)

To reduce the salinity in by ½, apply approximately 0.23 n of irrigation water per n of root zone

To reduce salinity to ¼ of the original value, apply approximately 0.44 n of water per n of soil

(from Hoffman, 1980)

Salt and sodium related water quality parameters

Water quality test	What the test measures	Effect of chemical property on soil
pH	Alkalinity/acidity balance	Not directly important to trees. Very high pH water (> 8.4) may contain sodium that can damage soil structure.
Electrical Conductivity (EC)	Dissolved salts	Increased salt concentration in water helps maintain soil structure, but may damage plants.
Sodium Adsorption Ratio (SAR)	Relative concentrations of sodium, calcium, and magnesium	The higher the SAR, the greater the risk of damaging soil structure.
Residual sodium carbonate (RSC)	Carbonate anions minus calcium and magnesium	When RSC is positive, calcium is lost from the soil solution when it combines with carbonates, increasing sodium hazard.

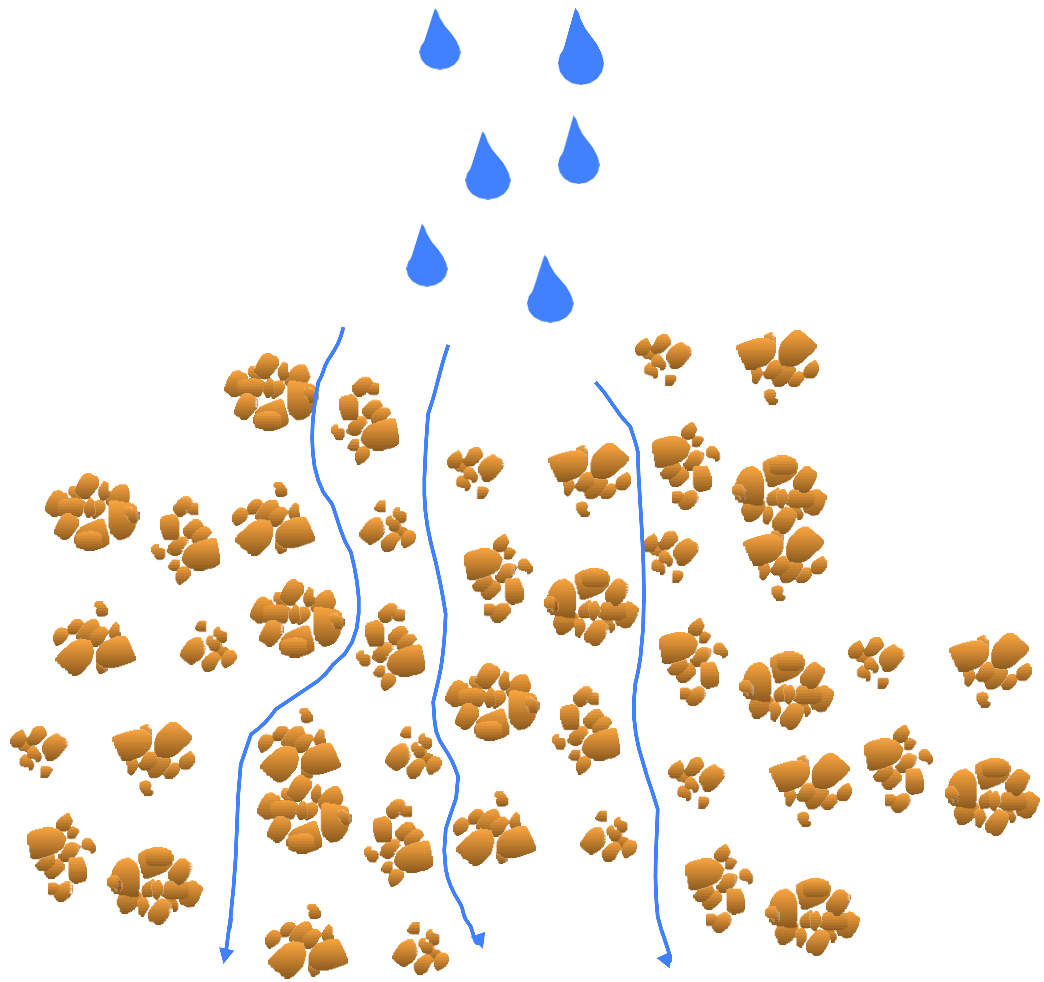
Units for water test parameters

Water Property		Symbol	Units
Total salinity	Electrical Conductivity	EC	dS/m or mmhos/cm
	Total Dissolved Solids	TDS	mg/L or ppm
Sodium Hazard	Sodium Adsorption Ratio	SAR	–
Cations	calcium	Ca	meq/L or ppm (same as mg/L)
	magnesium	Mg	
	sodium	Na	
	potassium	K	
Anions	boron	BO_3	
	bicarbonate	HCO_3	
	carbonate	CO_3	
	chloride	Cl	
	nitrate	NO_3	
	sulfate	SO_4	

Some useful conversions

Water Property	Symbol	Conversion
Electrical Conductivity	EC	EC (dS/m) x 640 = TDS (ppm)
Total Dissolved Solids	TDS	
Sodium Adsorption Ratio	SAR	Calculated from Na, Ca, Mg concentrations
Calcium	Ca	ppm ÷ 20 = meq/L
Magnesium	Mg	ppm ÷ 12.2 = meq/L
Potassium	K	ppm ÷ 39.1 = meq/L
Sodium	Na	ppm ÷ 23 = meq/L
Borate	BO_3	ppm ÷ 19.6 = meq/L
Bicarbonate	HCO_3	ppm ÷ 61 = meq/L
Carbonate	CO_3	ppm ÷ 30 = meq/L
Chloride	Cl	ppm ÷ 35.5 = meq/L
Nitrate	NO_3	ppm ÷ 62 = meq/L
Sulfate	SO_4	ppm ÷ 48 = meq/L

Aggregate formation and stability are important because water and air move mostly in large pores between aggregates. Also, plant roots grow through the large spaces between aggregates.



In all but the sandiest soils, dispersed (unaggregated) clays plug soil pores and impede water infiltration and soil drainage. High sodium levels tend to disperse soil clays.

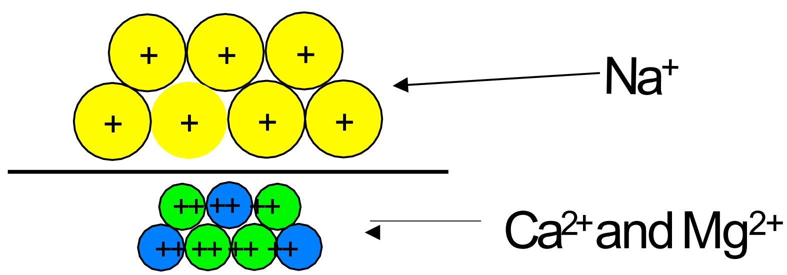
Typical soil infiltration rates are affected by sodium

Soil Texture	Infiltration Rate (in/hr)
Sand	2
Sandy loam	1
Loam	0.5
Clay loam	0.25
Sandy clay loam	0.10

Soils with high Sodium Adsorption Ration and poor soil structure will likely have infiltration rates much slower than those shown here

Sodium Adsorption Ratio

The ratio of 'weak' to 'strong' soil aggregators gives an indication of the likelihood of soil dispersion:

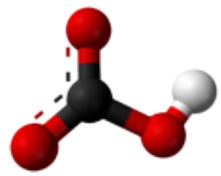


Acceptable irrigation water SAR is affected by irrigation water salinity (EC) levels

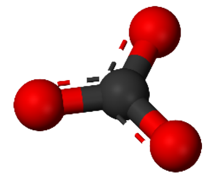
- Higher SAR values are acceptable if the water is salty (high EC)
- Low EC waters are more sensitive to high SAR

	Risk of water infiltra,on problem		
	Low	Moderate	High
SAR	EC of water (dS/m or mmhho/cm)		
0 -3	above 0.7	0.7 – 0.2	below 0.2
3 -6	above 1.2	1.2 – 0.3	below 0.3
6 -12	above 1.9	1.9 – 0.5	below 0.5
12 -20	above 2.9	2.9 – 1.3	below 1.3
20 -40	above 5.0	5.9 – 2.9	below 2.9

Carbonates and Bicarbonates in irrigation water



bicarbonate



carbonate

Carbonate and bicarbonate can combine with calcium, forming insoluble calcium carbonate, and taking calcium out of solution

carbonate + calcium → calcium carbonate

Residual sodium carbonate is a measure of the potential of carbonates and bicarbonates in irrigation water to tie up calcium

$$Residual\ Sodium\ Carbonate = (bicarbonate + carbonate) - (calcium + magnesium)$$

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

$$units = meq/L$$

Residual sodium carbonate hazard in irrigation water

	None	Slight to Moderate	Severe
RSC	< 1.25	1.25 – 2.5	> 2.5

Acid Injection

- Lower water pH
  - Target pH 7.0 or below
    - For concrete–lined ditches: 6.8 -7.0
    - For drip, microsprinklers: 6.5
- Amount of acid to add can be found in tables:

Bicarbonate in water	Sulfuric acid required per acre–inch of water (additional acid is required for water containing carbonate)		
(mg/L or ppm)	(meq/L)	(lb)	(gal)
50	0.8	8.6	0.6
100	1.6	17.2	1.1
200	3.3	34.3	2.3
400	6.6	68.7	4.6

or calculated: A x B x C = oz acid per 1,000 gallons water to lower pH to 6.4

A is determined by starting pH

Water pH	A
6.7	0.249
6.9	0.342
7.1	0.400
7.3	0.437
7.5	0.460
7.7	0.475
7.9	0.484
8.1	0.490
8.3	0.494
8.5	0.496

B is the sum of carbonate and bicarbonate (in meq/L)

C is determined by the type of acid used

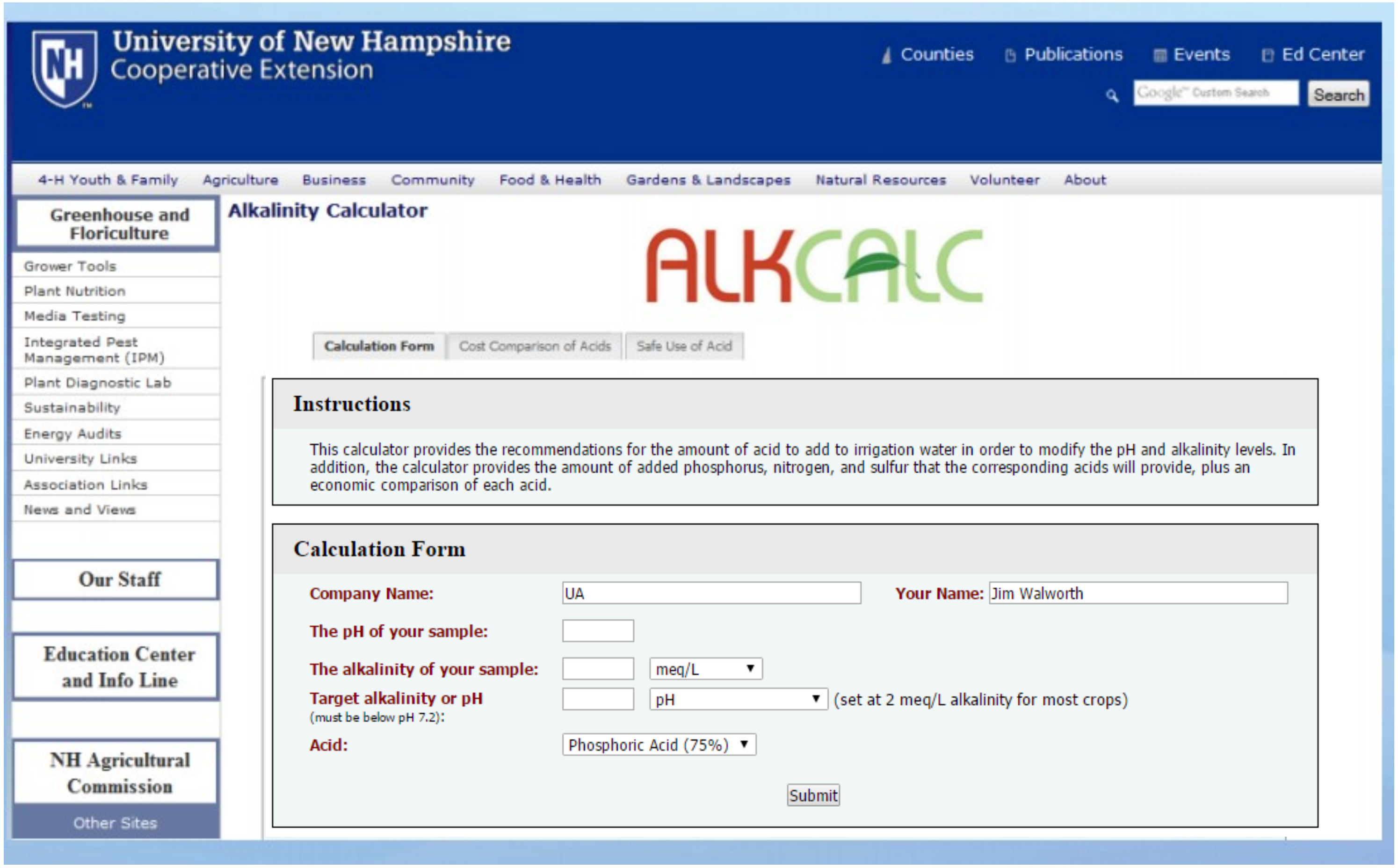
Acid source	C
75% phosphoric	10.60
85% phosphoric	8.74
93% sulfuric	3.72
61% nitric	15.60

Example:

- Starting water pH = 7.5
- Carbonate + bicarbonate = 3.4 meq/L
- Using 75% phosphoric acid

0.460 x 3.4 x 10.6 = add 16.5 oz/1000 gal water or with an online calculator

http://extension.unh.edu/Agric/AGGHFL/alk_calc.cfm



Input Variables

Company Name:	UA	Your Name:	Jim Walworth
Sample pH:	7.5	Sample alkalinity:	3.4 meq/L
Target alkalinity or pH:	6.4 pH	Acid:	Phosphoric Acid (75%)

Calculated Information

Alkalinity before acid addition:		Alkalinity after acid addition:	
meq/L:	3.40	meq/L:	1.90
or ppm of HCO3:	207.5	ppm of HCO3:	116.2
or ppm of CaCO3:	170.2	ppm of CaCO3:	95.3
		Final pH:	6.40

Alternative Acids to Add to Irrigation Water

Amounts	Phosphoric Acid (75%)
For Small Volumes	
ml per liter	0.115
fl. oz. per gallon	0.015
ml per gallon	0.434
For a 1:100 Injector	
fl. oz. per gallon (conc.)	1.47
ml per gallon (conc)	43.35
For a 1:128 Injector	
fl. oz. per gallon (conc.)	1.88
ml per gallon (conc)	55.49
For a 1:200 Injector	
fl. oz. per gallon (conc.)	2.93

Sulfur Burners – alternative to acid injection

Sulfur + O_2 → H_2SO_3 (sulfurous acid)

- Elemental sulfur is combusted, forms sulfurous acid
  - Sulfurous acid is injected directly into irrigation water
  - Safer than handling sulfuric acid
  - Sulfurous acid is a weak acid – sulfuric acid is a strong acid

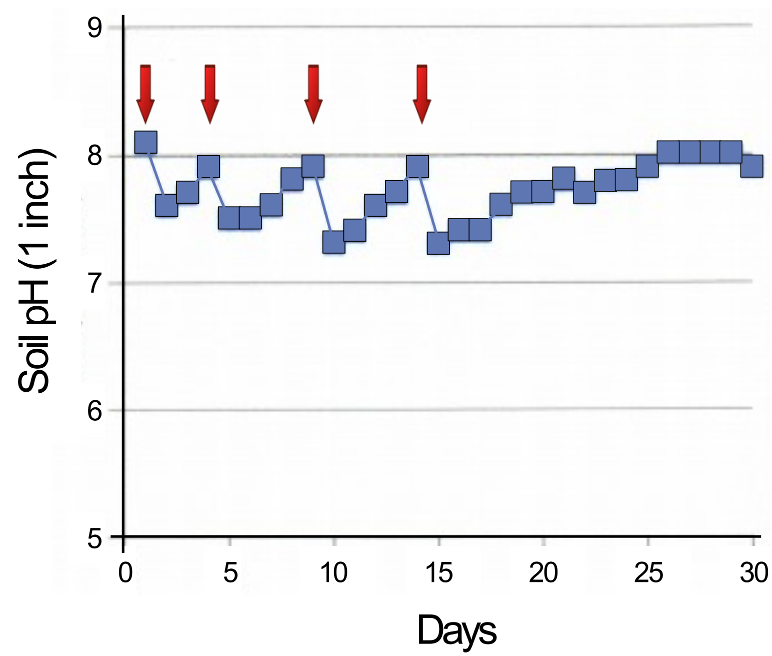
Sulfur combustion

$S + O_2 \rightarrow SO_2$

Water reaction

$SO_2 + H_2O \rightarrow H_2SO_3$

Acid injection is used to adjust irrigation water, not to lower soil pH



Effect of repeated liquid sulfuric acid applications on the pH of the surface inch of soil. Acid was applied four times (Day 1, 4, 9, and 14). Soil pH reduction is temporary – acid injection is used to lower SAR.

Gypsum Injection

Gypsum ($CaSO_4 \cdot 2H_2O$)

- Can be used to increase calcium concentration in irrigation water (alternative to acidifying)
- Soil applied or injected into irrigation water


QUESTIONS ?

Irrigation Water Boron: Desirable Range		
Boron	Clay, clay loam	< 0.5
	Loam	0.5 – 1.0
	Sand, loamy sand	1 – 1.5

Water treatment methods and their applicability

	Total Dissolved Solids	Bicarbonate & Carbonate	Calcium & Magnesium	Iron & Manganese	Boron	Fluoride
Reverse osmosis	X	X	X	X	X	X
Deionization	X	X	X	X	X	X
Anion exchange		X			X	X
Water sonening			X	X		
Activated carbon						
Acid injection		X				

Things that should be on your irrigation water report

Ca,ons		Anions		Other	
Calcium	Ca^{2+}	Chloride	Cl^{-}	Total Dissolved Solids or Electrical Conductivity	TDS or EC
Magnesium	Mg^{2+}	Boron	BO_3^{3-}	Residual Sodium Carbonate	RSC*
Sodium	Na^{+}	Carbonate	CO_3^{2-}	Sodium Adsorption Ratio	SAR*
Potassium	K^{+}	Bicarbonate	HCO_3^{-}	Acidity/Alkalinity	pH
		Sulfate	SO_4^{2-}		
		Nitrate	NO_3^{-}		

*Calculated from concentrations of anions and cations in the water

Isn't there an easier way?

(No, there isn't)