WQ - 1 – Irrigation Water Quality Sampling

Why Sample: Effects of Poor Water Quality on Soils

Irrigation water quality refers to the kind and amount of salts present in the water and their effects on crop growth and development. Soil samples as well as water quality samples must be taken to determine the quality. If levels of calcium, magnesium, and sodium, as well as chlorides, sulfates, and bicarbonates, as a group or alone, are too high, crop growth can be hurt. High levels can even cause crop failure. Often it is associated with poor soil structure.

Crop growth reductions because of dissolved substances in the soil are similar to drought-stressed effects. An osmotic gradient on salty soils is formed. Water uptake by plant roots is increasingly restricted as the concentration of soil salts increases. Because of this, as soil salts build up in the soil, more frequent irrigation is necessary to help flush out salts and reduce water stress.

A breakdown of soil structure is a major effect of elevated sodium. Soil aggregates are bonded by calcium and magnesium. High levels of dissolved sodium tend to displace these bonding elements and disperse the aggregates. As sodium increases, dispersion increases and soil tilth declines. Soil dispersion caused by sodium can make soils run together, crust easier, and can limit water infiltration.

How to Take Irrigation Water Quality Samples

Levels and specific makeup of dissolved substances in irrigation water affect crop productivity and soil structure. They also determine if water is suitable for irrigation.

Water analyses can only be as accurate as the sample taken. Contact your laboratory first to obtain the form and any specific procedures to follow. Follow these simple guidelines when collecting a water sample:

Containers and Handling

Sample early in the week to avoid having the sample sit in a lab over the weekend. Samples should be collected in a new clean, plastic bottle (at least a pint) with a screw cap. Rinse the plastic bottle and cap 3 times with the water you wish to sample to eliminate any contamination. Fill the bottle to the top and cap tightly. Wipe the bottle dry. Clearly identify each container with a simple sample identification which matches the request form for the laboratory. Tape the bottle shut so that it doesn't leak. When mailing, place bottles in a box and pack with a loose, soft packing material to prevent crushing. Avoid glass containers, as boron concentrations may change and glass has higher potential for breakage. Some samples may require overnight delivery. If the sample can't be sent immediately, refrigerate it before sending to the laboratory. Keep good records of the date and location of each sample. This can best be done by keeping a copy of the laboratory information sheet that must be submitted with each sample.

Well Water

Let the pump operate twenty minutes to an hour before taking the sample to be sure the water is representative of what is being tested. Take the sample from water at the pump so that residues from the lines do not contaminate the sample. If two or more wells supply an irrigation system, one sample may be taken from the system after pumping (flushing) for at least one hour. However, if a water test indicates a problem, all wells supplying the system will need to be tested individually to determine the source of the problem. Sometimes one poor quality well can dramatically reduce the quality of a mixture.

Other Water Sources

Testing should also be done on irrigation water from ponds, reservoirs, streams, canals, or other surface water sources. Samples can be obtained by collecting water from a faucet near the pumping station after operating for twenty minutes or longer. For irrigation water sources where no pump is present, obtain samples by attaching a clean bottle to a pole or extension and collecting and mixing several samples into a "composite" which is sent to the laboratory. Samples from lakes, streams, or ponds should be taken below the surface for a representative sample. Where sprinkler or pivot irrigated, fill the bottle directly from the sprinkler or point of emission.

What Analyses to Request

In most cases, a routine irrigation water analysis is the most appropriate test to request for irrigation water. Regardless of laboratory selected, be certain that the analysis includes the three major factors – total soluble salts, sodium hazard (SAR) and individual potentially toxic ions. The most recommended analyses to request are:

Ammonia (for nitrogen loading)
Carbonates
pH
R_{adj}
Bicarbonates
Chlorides
Phosphorus
Sodium
Boron
Magnesium
Potassium
Sulfate
Calcium
Nitrate nitrogen
Salinity
Total nitrogen
Electrical Conductivity
(for nitrogen loading)
SAR
(for nitrogen loading)
Fluoride
Total dissolved solids
Special Analyses Processing -
For microbiological analysis see instructions for specific lab.

Water Quality and Subsurface Drip Irrigation systems:

The irrigation water to be used in a drip system should be evaluated carefully to assess any potential clogging problems. Materials suspended in the water, such as sand, silt, and algae, can block emitter flow passages or settle out in the drip lines. Other contaminants, such as calcium, bicarbonate, iron, manganese, and sulfide, can also precipitate to clog emitter flow passages. All water needs to be tested to determine levels of dissolved salts, pH, and turbidity (sediment levels). Growers need to be aware of high levels of pH (7.5) and high dissolved bicarbonate levels (=> 5.6 meq/liter). If water quality analysis indicates these levels, sulfuric acid and/or gypsum should be injected to acidify the water to lower the pH to prevent the emitters from clogging with precipitates. A pH of 6.5 is favorable for injecting fertilizers or other agricultural chemicals into the system.

NM Certified Laboratories for Drinking Water Analyses – Can be Used for Irrigation

Albuquerque Water Quality	*	Albuquerque, NM	(505) 873 6249
Assaigai Aanlytical Laboratories	* +	Albuquerque, NM	(505) 345 8964
City of Carlsbad	*	Carlsbad, NM	(505) 887 1191
Diagnostic & Technology Center, Inc.	*	Alamogordo, NM	(505) 434 4944
Indepth Water Testing	*	Santa Fe, NM	(505) 471 2023
City of Farmington Env. Lab	*	Farmington, NM	(505) 599 1373
Gallup Micro Biology Lab	*	Gallup, NM	(505) 863 2001
Hall Environmental Analysis	+	Albuquerque	(505)345 3975
City of Hobbs	*	Hobbs, NM	(505) 397 9315
International Lubrication & Fuel Consultants, Inc.	*	Rio Rancho, NM	(505) 892 1666
Kramer & Associates, Inc	*	Albquerque, NM	(505) 881 0243
City of Las Vegas	*	Las Vegas, NM	(505) 454 1533
Micro Biology Lab	*	Milan, NM	(505) 287 2208
NM American Water Co.	*	Clovis, NM	(505) 763 5538
NM Water Testing Lab, Inc	*	Espanola, NM	(505) 753 6028
OMI Inc	*	Farmington, NM	(505) 325 6953
Pinnacle	+	Albuquerque	(505) 344 3777
Raton Water Works	*	Raton, NM	(505) 445 3861
Town of Red River	*	Red River, NM	(505) 754 6671
Scientific Labaratory Division/DOH	* +	Albquerque, NM	(505) 841 2510
City of Silver City	*	Silver City, NM	(505) 538 3731
SWAT Lab	* +	Las Cruces, NM	(505) 646 4422
Triangle Laboratories	dioxin	Research Triangle Park, NC	(919) 544 5729
City of Tucumcari	*	Tucumcari, NM	(505)461-4372
* for microbiology + for chemicals		Source: http://www.nmenv.state.nm.us/dwb/certified_labs.html	Updated 9/27/06

(WQ – 2)

SOLUBLE SALTS

(Irrigation Water Quality example)

Dominant Cations (Ions with a positive charge)			Dominant Anions (Ions with a negative charge)		
Calcium	Ca^{++}	80 ppm	**Sulfate**	$SO4^{--}$	192 ppm
Sodium	Na^{+}	115 ppm	**Chloride**	Cl^{-}	92 ppm
Magnesium	Mg^{++}	14 ppm	**Bicarbonate**	$HCO3^{-}$	183 ppm
Potassium	K^{+}	8 ppm	**Carbonate**	$CO3^{--}$	6 ppm

Total ppm: **217 ppm (cations)** + **473 ppm (anions)** = **690 ppm = 690 mg/l (Soluble Salts)**

TDS (ppm) = EC (dS/m) x 640, for EC between 0.1 and 5.0 dS/m
TDS (ppm) = EC (dS/m) x 800, for EC > 5.0 dS/m

- TDS = Total Dissolved Solids
- ppm = parts per million; mg/l = milligrams/liter (ppm = mg/l)
- EC = Electrical Conductivity

690 ÷ 640 ≈ 1.08 dS/m (EC)
(dS/m = mmhos/cm = mS/cm)
dS/m = deciSiemens/meter
mmhos/cm =milliMhos/centimeter
mS/cm = milliSiemens/centimeter
2.72 x ppm = lbs. of salts/ac-ft
(2.72 x 690 ppm = 1,877 lbs/ac-ft)

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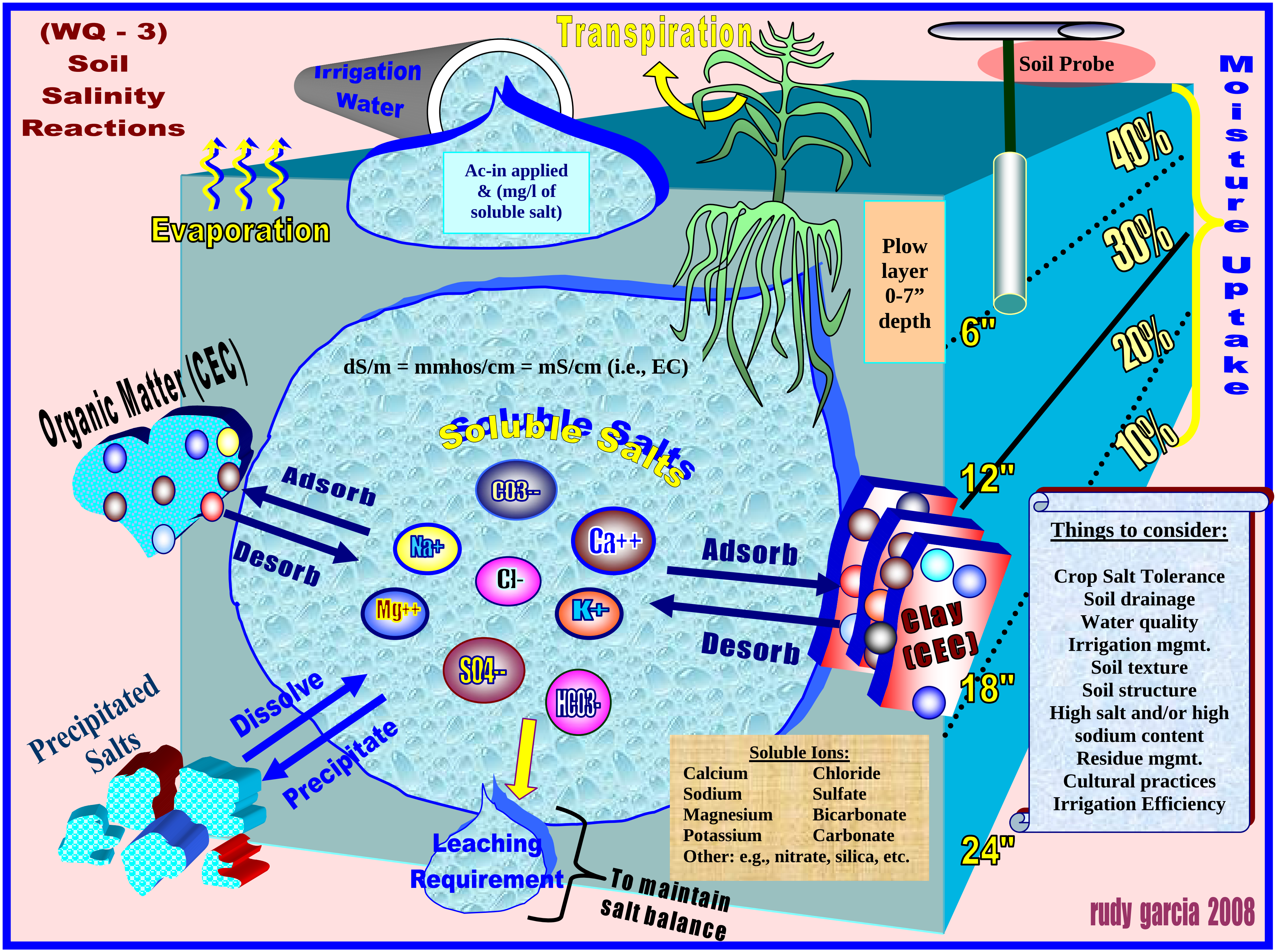
(WQ - 3)
Soil
Salinity
Reactions
Irrigation
Water
Ac-in applied
& (mg/l of
soluble salt)
Transpiration
Soil Probe
Evaporation
Moisture Uptake
40%
30%
20%
10%
Plow
layer
0-7”
depth
6"
12"
18"
24"
dS/m = mmhos/cm = mS/cm (i.e., EC)
Organic Matter (CEC)
Soluble Salts
Adsorb
Desorb
CO3--
Na+
Ca++
Cl-
Mg++
K+
SO4--
HCO3-
Adsorb
Desorb
Clay
(CEC)
Precipitated
Salts
Dissolve
Precipitate
Leaching
Requirement
To maintain
salt balance
Soluble Ions:
Calcium
Sodium
Magnesium
Potassium
Chloride
Sulfate
Bicarbonate
Carbonate
Other: e.g., nitrate, silica, etc.
Things to consider:
Crop Salt Tolerance
Soil drainage
Water quality
Irrigation mgmt.
Soil texture
Soil structure
High salt and/or high
sodium content
Residue mgmt.
Cultural practices
Irrigation Efficiency
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(WQ – 4) Irrigation Water Salinity & Sodium Adsorption Ratio (SAR) Assessment Guide

Irrigation Water Lab Analysis for Soluble Salts and SAR (mg/l = milligrams/liter; meq/l = milliequivalents/liter)

	Major Cations (ions with a positive charge)	example		Enter Lab Results			Major Anions (ions with a negative charge)	example		Enter Lab Results	
		mg/l	meq/l	mg/l	meq/l			mg/l	meq/l	mg/l	meq/l
Hardness	Calcium (Ca^{++}) **20.04 mg/meq**	80	4				Chloride (Cl^{-}) **35.46 mg/meq**	92	2.6		
Hardness	Magnesium (Mg^{++}) **12.16 mg/meq**	14	1.2				Sulfate ($SO4^{--}$) **48.03 mg/meq**	192	4		
	Sodium (Na^{+}) **22.99 mg/meq**	115	5			Alkalinity	Bicarbonate (HCO_3^{-}) **61.02 mg/meq**	183	3		
	Potassium (K^{+}) **39.10 mg/meq**	8	0.2			Alkalinity	Carbonate (CO_3^{--}) **30.01 mg/meq**	6	0.2		
	Sum of Total Cations:	**217**	**10.4**				Sum of Total Anions:	**473**	**9.8**		

Total Dissolved Solids (i.e., Soluble Salts) is: 217 mg/l + 473 mg/l = 690 mg/l (or 690 ppm). **0.23 x TDS (ppm) = lbs. of salts/ac-in**
690 mg/l ÷ 640 ≈ ECiw of 1.1 dS/m (i.e., Electrical Conductivity of Irrigation Water in decisiemens/meter)

Irrigation Water Salinity Assessment

Salinity (Soluble Salts): affects crop water availability	Degree of Restriction on Use – ECiw (dS/m)		
Note: Be sure to compare the Irrigation Salinity (ECiw) with the Soil Test (ECe), in order to evaluate the potential yield reduction of your crop (i.e., Refer to a Crop Threshold Soil Salinity (ECe(ct)) Table)	**None**	**Slight to Moderate**	**Severe**
	< 0.7	**0.7 – 3.0**	**> 3.0**

Irrigation Water Quality and its potential effects on Infiltration

The amount of **Sodium** and **soluble salts** in the Irrigation Water affects the rate of water infiltration into the soil. This is evaluated using the **SAR** (**Sodium Adsorption Ratio**) and Electrical Conductivity of the Irrigation Water **(ECiw in dS/m)**.

Use meq/l for calculating the SAR

SAR = Na/√(Ca + Mg)/2

SAR	Degree of Restriction on Use – ECiw (dS/m): None	Slight to Moderate	Severe
0 – 3	**> 0.7**	**0.7 – 0.2**	**< 0.2**
3 – 6	**> 1.2**	**1.2 – 0.3**	**< 0.3**
6 – 12	**> 1.9**	**1.9 – 0.5**	**< 0.5**
12 – 20	**> 2.9**	**2.9 – 1.3**	**< 1.3**
20 - 40	**> 5.0**	**5.0 – 2.9**	**< 2.9**

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(WQ – 5) Water Quality Infiltration Assessment Guide

ECiw (dS/m)	SAR		* adj.RNa			
	High Ca Low Na	High Na Low Ca	High Ca Low Na Low HCO_3	High Ca Low Na High HCO_3	High Na Low Ca Low HCO_3	High Na Low Ca High HCO_3
0.5	0.71	4.0	0.64	0.9	3.2	4.3
1.0	1.0	5.7	1.2	1.6	5.7	7.2
2.0	1.41	8.1	2.1	2.8	9.7	11.5
3.0	1.73	9.9	3.0	3.7	13.1	14.8
4.0	2.0	11.4	3.7	4.5	15.6	17.6

ECiw =Electrical Conductivity of irrigation water; SAR = Sodium Adsorption Ratio; adj.RNa = adjusted Residual Sodium (the adj.RNa replaces the older adj.SAR method which is no longer recommended)

Infiltration Assessment

(Affects infiltration rate of water into the soil. Evaluated using ECiw & SAR or adj.RNa together)

SAR Or adj.RNa	Degree of Restriction on USE ECiw (dS/m)		
	None	Slight to Moderate	Severe
0 – 3	>0.7	0.7 - 0.2	<0.2
3 – 6	>1.2	1.2 – 0.3	<0.3
6 – 12	>1.9	1.9 – 0.5	<0.5
12 – 20	>2.9	2.9 – 1.3	<1.3
20 - 40	>5.0	5.0 – 2.9	<2.9

Potential Reduction in Infiltration due to SAR (or adj.RNa) and ECiw (Soil Type determines degree of problem)

Least affected-------- -------Moderately affected-------- ------Most affected

Coarse	Moderately Coarse	Medium	Moderately Fine	Fine
Sands, fine Sands, V. fine Sands, Loamy Sands, Loamy F. Sands, LoamyV. F. Sand	Sandy Loam, fine Sandy Loam	Very fine Sandy Loam, Loam, Silt Loam, Silt	Sandy Clay Loam, Silty Clay Loam, Clay Loam	Sandy Clay, Silty Clay, Clay

<u>NOTE:</u> the SAR and adj.RNa calculations were based on the following concentrations:
High Ca = 70% of meq./l of cations
Low Na = 20% of meq./l of cations
Low HCO3 = 20% of meq./l of anions
Low Ca = 20% of meq./l of cations
High Na = 70% of meq./l of cations
High HCO3 = 70% of meq./l of anions
Magnesium was kept at 10% of meq./l of cations

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Crop Salt Tolerances

Crop (name)	Yield loss 0% ECe[1]	Yield loss 0% ECw[2]	Yield loss 10% ECe[1]	Yield loss 10% ECw[2]	Yield loss 25% ECe[1]	Yield loss 25% ECw[2]	Yield loss 50% ECe[1]	Yield loss 50% ECw[2]	Maximum ECe[3]
Alfalfa	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	15.5
Almond	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.7	7.0
Apple	1.7	1.0	2.3	1.6	3.3	2.2	4.8	3.2	8.0
Apricot	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	6.0
Barley	8.0	5.3	10.0	6.7	13.0	8.7	18.0	12.0	28.0
Beans	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.5
Beets	4.0	2.7	5.1	3.4	6.8	4.5	9.6	6.4	15.0
Bermuda Grass	6.9	4.6	8.5	5.7	10.8	7.2	14.7	9.8	22.5
Blackberry	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0
Boysenberry	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0
Broccoli	2.8	1.9	3.9	2.6	5.5	3.7	8.2	5.5	13.5
Cabbage	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12.0
Cantaloupe	2.2	1.5	3.6	2.4	5.7	3.8	9.1	6.1	16.0
Carrot	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.1	8.0
Clover	1.5	1,0	2.3	1.6	3.6	2.4	5.7	3.8	10.0
Corn, Grain & Silage	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Corn Silage	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15.5
Corn, Sweet	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Cotton	7.7	5.1	9.6	6.4	13.0	8.4	17.0	12.0	27.0
Cucumber	2.5	1.7	3.3	2.2	4.4	2.9	6.3	4.2	10.0
Fescue, Tall	3.9	2.6	5.8	3.9	8.6	5.7	13.3	8.9	23.0
Grape	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12.0
Lettuce	1.3	0.9	2.1	1.4	3.2	2.1	5.2	3.4	9.0
Love Grass	2.0	1.3	3.2	2.1	5.0	3.3	8.0	5.3	14.0
Meadow Foxtail	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.6	12.0
Onion	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.5
Orchard Grass	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	17.5
Peach	1.7	1.0	2.2	1.4	2.9	1.9	4.1	2.7	6.5
Pear	1.7	1.0	2.3	1.6	3.3	2.2	4.8	3.2	8.0
Pecan[4]	1.9	1.3**	2.4*	1.6**	3.2*	2.4**	4.6	3.0**	8.0*
Pepper	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	8.5
Potato, Irish	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Potato, Sweet	1.5	1.0	2.4	1.6	3.8	2.5	6.0	4.0	10.5
Radish	1.2	0.8	2.0	1.3	3.1	2.1	5.0	3.4	9.0
Raspberry	1.0	0.7	1.4	1.0	2.1	1.4	3.2	2.1	5.5
Ryegrass, Perennial	5.6	3.7	6.9	4.6	8.9	5.9	12.2	8.1	19.0
Safflower	5.3	3.5	6.2	4.1	7.6	5.0	9.9	6.6	14.5
Soybean	5.0	3.3	5.5	3.7	6.2	4.2	7.5	5.0	10.0
Spinach	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7	15.0
Strawberry	1.0	0.7	1.3	0.9	1.8	1.2	2.5	1.7	4.0
Sudan Grass	2.8	1.9	5.1	3.4	8.6	5.7	14.4	9.6	26.0
Sugar Beet	7.0	4.7	8.7	5.8	11.0	7.5	15.0	10.0	24.0
Tomato	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	12.5
Trefoil, Big	2.3	1.5	2.8	1.9	3.6	2.4	4.9	3.3	7.5
Trefoil, Birdsfoot	5.0	3.3	6.0	4.0	7.5	5.0	10.0	6.7	15.0
Vetch	3.0	2.0	3.9	2.6	5.3	3.5	7.6	5.0	12.0
Wheat	6.0	4.0	7.4	4.9	9.5	6.4	13.0	8.7	20.0
Wheatgrass, Crested	3.5	2.3	6.0	4.0	9.8	6.5	16.0	11.0	28.5
Wheatgrass, Fairway	7.5	5.0	9.0	6.0	11.0	7.4	15.0	9.8	22.0
Wheatgrass, Tall	7.5	5.0	9.9	6.6	13.3	9.0	19.4	13.0	31.5
Wild Rye, beardless	2.7	1.8	4.4	2.9	6.9	4.6	11.0	7.4	19.5

[1] ECe is the electrical conductivity of saturated soil extract, reported in millimhos per centimeter at 25°C.

[2] ECw is the electrical conductivity of the irrigation water, reported in millimhos per centimeter at 25°C.

[3] Maximum ECe is the conductivity of saturated soil extract, reported in millimhos per centimeter at 25°C, at which the plant dies.

[4] Complete data is not currently available for pecans. The * is an interpolation between the 0% and 50% range. The ** for ECw is calculated as ECe x 0.67, which is a general rule of thumb for these ratios under average conditions. RDFischer 2/09

(WQ – 7) Salinity Assessment GUIDE for Selected Crops

CROP	Salt Tolerance	*ECe(ct) Crop Threshold (dS/m)	% Yield Reduction per unit increase above ECe(ct)	Irrigation ECiw (dS/m)					Irrigation ECiw (dS/m)				
				0.5	1.0	2.0	3.0	4.0	0.5	1.0	2.0	3.0	4.0
				Soil ECe will concentrate about 1.5 x the ECiw in the top root zone ** % Yield Reduction					% Leaching Fraction (LF) for conventional irrigation **$Fc = ECe_{(ct)}/ECiw$** **$***LF = 0.3086/Fc^{1.702}$**				
Barley	T	8.0	5.0	0	0	0	0	0	0.3	1	3	6	10
Cotton	T	7.7	5.2	0	0	0	0	0	0.3	1	3	6	10
Bermuda Grass	T	6.9	6.4	0	0	0	0	0	0.4	1	4	8	12
Triticale	T	6.1	2.5	0	0	0	0	0	0.4	1	5	9	15
Sorghum	MT	6.8	16	0	0	0	0	0	0.4	1	4	8	13
Oats	MT	6.0	5.6	0	0	0	0	0	0.5	2	5	10	16
Wheat Common	MT	6.0	7.1	0	0	0	0	0	0.5	2	5	10	16
Tall Fescue	MT	3.9	5.3	0	0	0	3	11	1	3	10	20	32
Peanut	MS	3.2	29.0	0	0	0	38	81	1	4	14	28	45
Tomato	MS	2.5	9.9	0	0	5	20	35	2	7	21	42	>50
Alfalfa	MS	2.0	7.3	0	0	7	18	29	3	10	31	>50	>50
Pecan	MS	1.9	16.6	0	0	18	43	68	3	10	34	>50	>50
Corn Grain	MS	1.7	12.0	0	0	16	34	52	4	13	41	>50	>50
Strawberry Clover	MS	1.5	12.0	0	0	18	36	54	5	16	>50	>50	>50
Pepper	MS	1.5	14.0	0	0	21	42	63	5	16	>50	>50	>50
Lettuce	MS	1.3	13.0	0	3	22	42	61	6	20	>50	>50	>50
Peach	S	1.7	21.0	0	0	27	59	90	4	13	41	>50	>50
Apple	S	1.3	17.5	0	4	30	56	82	6	20	>50	>50	>50
Onion	S	1.2	16.0	0	5	29	53	77	7	23	>50	>50	>50
Green Bean	S	1.0	19.0	0	10	38	67	95	10	31	>50	>50	>50

$*ECe_{(ct)}$ is the Crop Threshold Soil Salinity. It is the maximum mean root zone soil salinity at which yield reductions will not occur. **Due to many variables governing salt balance, the calculated values are an estimate.

*** % LF needs to be evaluated with actual % Irrigation efficiencies.

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Irrigation water quality guidelines[1]				
Potential irrigation water quality problem	**Parameter**	**Degree of restriction on use**		
		None	**Slight to moderate**	**Severe**
Salinity (affects crop water availability)	**ECiw (mmho/cm)**	**< 0.7**	**0.7 – 3.0**	**>3.0**
	or TDS (mg/l)	**< 450**	**450 – 2,000**	**> 2,000**
Infiltration (affects water infiltration rate, evaluated by using ECiw and SAR together)	**SAR**	**ECiw (mmho/cm)**		
	0 – 3	**> 0.7**	**0.7 – 0.2**	**< 0.2**
	3 – 6	**> 1.2**	**1.2 – 0.3**	**< 0.3**
	6 – 12	**> 1.9**	**1.9 – 0.5**	**< 0.5**
	12 - 20	**> 2.9**	**2.9 – 1.3**	**< 1.3**
	20 - 40	**> 5.0**	**5.0 – 2.9**	**< 2.9**
Specific ion toxicity (affects sensitive crops)				
(Na^+) surface irrigation	**SARadj**	**< 3**	**3 - 9**	**> 9**
sprinkler irrigation	**meq/l**	**< 3**	**> 3**	
(Cl^-) surface irrigation	**meq/l**	**< 4**	**4 – 10**	**> 10**
sprinkler irrigation	**meq/l**	**< 3**	**> 3**	
Boron **(B)**	**ppm/l**	**< 0.7**	**0.7 – 3.0**	**> 3.0**
(HCO_3^-) Bicarbonate (overhead sprinkler only)	**meq/l**	**< 1.5**	**1.5 – 8.5**	**> 8.5**

Plugging potential from irrigation water used in micro irrigation systems			
PROBLEM	**LOW**	**MEDIUM**	**SEVERE**
Physical			
Suspended solids (ppm)	**< 50**	**50 - 100**	**> 100**
Chemical			
pH	**< 7.0**	**7.0 – 8.0**	**>8.0**
TDS (ppm)	**< 500**	**500 – 2,000**	**> 2000**
Manganese (ppm)	**< 0.1**	**0.1 – 1.5**	**>1.5**
Iron (ppm)	**< 0.1**	**0.1 – 1.5**	**>1.5**
Hydrogen sulfide (ppm)	**< 0.5**	**0.5 – 2.0**	**>2.0**
Biological			
Bacteria pop. (no./ml)	**< 10,000**	**10,000 – 50,000**	**> 50,000**

[1] Adapted from Western Fertilizer Handbook, 2002, Ninth edition, California Plant Health Association, Interstate Publishers, Inc., Danville, Illinois.

(WQ – 9)Gypsum ($CaSO_4 \cdot 2H_2O$) & Elemental Sulfur (S^0) Soil Amendment GUIDE

NOTE: If you're not sure of the benefits of gypsum or elemental sulfur, then demonstrate on a small portion of a field & evaluate results.

Soil Texture	% Clay	CEC Range (meq/100 g)	Soil Bulk Density (g/cm^3)
Sands	2 – 8	2 – 6	1.65
Loamy Sands	2 – 14		1.6
Fine Sands			
Very Fine Sands	2 – 8		1.65
Loamy Fine Sands			
Loamy Very F. Sands	2 – 14		1.6
Sandy Loam			
Fine Sandy Loam	2 – 18	3 – 8	1.56
Very F. Sandy Loam			1.53
Loam	10 – 26	7 – 15	1.42
Silt Loam	2 – 26		1.46
Silt	2 – 10	10 – 19	1.47
Sandy Clay Loam	22 – 36		1.4
Silty Clay Loam			1.27
Clay Loam	28 – 38		1.32
Sandy Clay	38 – 54		1.33
Silty Clay	42 – 58	15 - 30	1.23
Clay	42 - 98		1.25

Cation Exchange Capacity (CEC) is based on % Clay & mineral type (e.g. Kaolinite, Montmorillonite) & % Organic Matter

Soils Intake Family	Inches Applied 1.0	2.0	3.0
	Infiltration Time (Hrs)		
0.1	2.8	10.5	22.3
0.3	1.0	3.5	6.8
0.5	0.63	2.0	3.8
0.75	0.48	1.5	2.8
1.0	0.33	1.0	1.8
1.25	0.28	0.8	1.5
1.5	0.23	0.7	1.3
1.75	0.20	0.6	1.1

Infiltration Assessment

SAR	Restriction on Use (Units: ECiw (dS/m)) None	Slight to Mod.	Severe
0 – 3	> 0.7	0.7 – 0.2	< 0.2
3 – 6	> 1.2	1.2 – 0.3	< 0.3
6 – 12	> 1.9	1.9 – 0.5	< 0.5
12 – 20	> 2.9	2.9 – 1.3	< 1.3
20 - 40	> 5.0	5.0 – 2.9	< 2.9

Soil Structure	Downward Movement of water
Single Grain	Rapid
Granular	Rapid
Blocky	Moderate
Prismatic	Moderate
Platy	Slow
Massive	Slow

constant x soil depth x bulk density x CEC x (initial SAR – final SAR) x multiplication factor ÷ gypsum purity ÷ 2000 = gypsum requirement

(23.1) x (feet) x (g/cm^3) x (meq/100 g) x (initial SAR – final SAR) x (1.25) ÷ (%) ÷ (2000) = (tons/ac)

Gypsum Example: 23.1 x 0.5 ft x 1.34 g/cm^3 x 14.0 meq/100 g x (13 – 6) x 1.25 ÷ 0.80 ÷ 2000 = 1.2 tons of Gypsum/ac

Sulfur Example: 1.3 tons/ac of pure gypsum needed x 0.19* = 0.25 tons of Elemental Sulfur/ac needed (or 494 lbs./ac)

<u>Considerations in the use of soil amendments</u>: Soils Intake Family, Water Quality (ECiw & SAR), Soil Structure, Stratified Soils, Irrigation Water Management, crop rotations (residue management), leaching requirement, tillage operations (i.e., Soil Conditioning Index (SCI) and Soil Tillage Intensity Rating (STIR)), % Soil Organic Matter, etc. **Important:** Are Soils characterized as Saline, Saline-Sodic or Sodic.

*Use 0.19 to convert an equivalent amount of pure gypsum into an S^0 requirement (Ref. NRCS Salinity Mgmt. for Soil & Water – pg. 5.42). rudy garcia 2008