INTERPRETING IRRIGATION WATER ANALYSIS II - PLANT NUTRITION AND WATER QUALITY

FACT SHEET

Irrigation water quality has a huge impact on soil and crop health from salinity and reduced water infiltration, toxicity, or the effects related to a group of miscellaneous water constituents. In some cases the use of irrigation water if not understood can actually strip nutrients from the crop and set the crop back due to nutritional imbalances that it causes.

When determining the quality of water for irrigation or the potential hazard of irrigation water the following needs to be considered:

Salinity
Water Infiltration Problems
Specific Ion Toxicity
Nutrient Status
Clogging Problems

Nutrition and Salinity

Excessive Salinity stunts the crops by reducing the availability of soil-water, slowing crop growth and restricting root development. With higher salinity water, sodium and chloride toxicity are also likely to be evident. The salinity status of irrigation water is determined by the water's EC (electrical conductivity) and is also expressed as Total soluble salts (TSS) or Total Dissolved Solids (TDS) Salts naturally occurring in irrigation water are dissociated into electrically charged ions. Increasing concentration of these ions increases the waters ability to conduct electricity. Calcium, magnesium and sodium are the positive charged ions, the negative charged anions consist primarily of bicarbonates, sulfates and chlorides. (see Table 1)

Water Infiltration Problems

Problems due to water infiltration due to water quality are usually related to either very low water salinity or to a high sodium absorption ratio (SAR). In either case , the calcium content of the water may be at a relatively low concentration. If the calcium in the soil–water is taken up by the crop is less than 2 me/l, there is a strong probability that the crop yield will be reduced due to a calcium deficiency. High sodium levels with low calcium levels affect soil structure and water infiltration, soil particle disperse or cement together. High sodium irrigation water is the principle cause of loss of permeability of soil, however other factors contribute to this problem. Bicarbonates and carbonates in irrigation water increase the potential for problem by reacting with soil calcium and magnesium to form insoluble compounds. Removing calcium and magnesium from soil creates room for sodium to accumulate on the soil colloid.

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Carbonate and Bicarbonates

Bicarbonates (HCO_3^-) concentration in irrigation waters is primarily important in its relation to calcium (Ca_2+) and Magnesium (Mg_2+). There is a tendency for both calcium and magnesium to react with bicarbonate in the ware and /or soil precipitating as either calcium carbonate ($CaCO_3$) or magnesium carbonate ($MgCO_3$). Since magnesium carbonate is the more soluble, there is less tendency for it to precipitate. The precipitation of either calcium of magnesium from a water as carbonate salts increases the relative proportion of sodium which directly raises the sodium hazard rating. The potential bicarbonate hazard rating is shown in the following.

Potential Bicarbonate Hazard

Potential Hazard			
None to Slight	Moderate	Severe	Very Severe
(ppm HCO_3)			
0-120	120-180	180-600	600+

bicarbonate

Residual Sodium Carbonate (RSC)

The residual Sodium carbonate is a quick test to determine if irrigation water can reduce free in the free calcium and magnesium in the soil. RSC is calculated by subtracting the water's calcium and magnesium form it s carbonate and bicarbonate. A negative value indicates little risk of sodium accumulation due to offsetting levels of calcium an magnesium. A positive value indicate that the bicarbonate and carbonate will rescue free calcium and magnesium in the soil, thereby creating room for sodium to accumulate.

The increase in sodium hazard due to bicarbonate can be determined by calculation the residual sodium carbonate as follows:

$$\mathbf{RSC = (CO_3^{2-}\ meq/L + HCO^{3-}\ meq/L) - (Ca^{2+}\ meq/L + Mg^{2+}\ meq/L)}$$

Sodium Adsorption Ratio

This is the most reliable index of the sodium hazard of irrigation water to from exchangeable sodium in the soil.

$$SAR = \frac{Na^+(meq\ /\ liter)}{\sqrt{\frac{Ca^{2+}(meq\ /\ liter + Mg^{2+}(meq\ /\ liter))}{2}}}$$

Because large amounts of bicarbonate in irrigation water can increase the sodium hazard in soils, the sodium adsorption ratio (SAR) should include an adjustment factor to account for the added effects the precipitation or dissolution of calcium in soils related to carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) concentrations. As the calcium is precipitation by the high HCO_3^- and CO_3^{2-}, it is easily displaced leaving sodium as the dominant cation. The soil structure can then change causing further drainage problems.

The adjusted SAR is as follows where the calculated pHc is used

$$\text{adj. SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}\left[1 + (8.4 - pHc)\right]$$

The calculation for pHc is taken from pHc = (pK2-pKc) = p(Ca + Mg) = pAlk see table 2

When pHc from the water test exceeds 8.4 irrigation water will actually strip nutrients from the soil making them less available to the growing crop.

GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION Table 1

Potential Irrigation Problem				Units	Degree of Restriction on Use		
					None	Slight to Mod	Severe
Salinity (affects crop water availability)							
	ECw			dS/m	0.7	0.7-3.0	>3.0
	or						
	TDS			mg/l	<450	450-2000	>2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)							
SAR	= 0-3		And ECw	=	.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)							
	Sodium (Na)						
	Surface irrigation			SAR	<3	3-9	>9
	Sprinkler irrigation			me/l	<3	>3	
	Chloride						
	Surface irrigation			me/l	<4	4-10	>10
	Sprinkler irrigation			me/l	<3	>3	
	Boron			mg/l	<0.7	0.7-3.0	>3.0
Miscellaneous Effects (affects susceptible crops)							
	Nitrogen (NO3-N)			mg/l	<5	5-30	>30
	Bicarbonate (HCO3)						
	(overhead sprinkling only)			me/l	<1.5	1.5-8.5	>8.5
	pH				Normal Range 6.5-8.4		

$pHc = (pK_2 - pK_c) + p(Ca + Mg) + pAlk$
pK_2 is the second dissociation constant for H_2SO_3 and pHc is the solubility constant for $CaCO_3$ both corrected for ionic strength.
P(Ca + Mg) is the negative logarithm of the molal concentration of calcium plus magnesium.
pAlk is the negative logarithm of the molal concentration of the total bases (CO_3 + HCO_3).
pH_c is theoretical, calculated pH of irrigation water in contact with lime and in equilibrium with soil CO_2.

Obtained From Water Analysis	(pk_2—pK_c) is obtained from using the sum of Ca+ Mg + Na in meq/L p(Ca + Mg) is obtained from using the sum of Ca + Mg in meq/L p(Alk) is obtained from using the sum of CO_3 + HCO_3 in meq/L

Table 2

Sum Concentration (meq/L)	pK_2-pK_c	P(Ca + Mg)	P(Alk)	Sum Concentration (meq/L)	pK_2-pK_c	P(Ca + Mg)	P(Alk)
.05	2.0	4.6	4.3	2.5	2.2	2.9	2.6
.10	2.0	4.3	4.0	3.0	2.2	2.8	2.5
.15	2.0	4.1	3.8	4.0	2.2	2.7	2.4
.20	2.0	4.0	3.7	5.0	2.2	2.6	2.3
.25	2.0	3.9	3.6	6.0	2.2	2.5	2.2
.30	2.0	3.8	3.5	8.0	2.3	2.4	2.1
.40	2.0	3.7	3.4	10.0	2.3	2.3	2.0
.50	2.1	3.6	3.3	12.5	2.3	2.2	1.9
.75	2.1	3.4	3.1	15.0	2.3	2.1	1.8
1.00	2.1	3.3	3.0	20.0	2.4	2.0	1.7
1.25	2.1	3.2	2.9	30.0	2.4	1.8	1.5
1.5	2.1	3.1	2.8	50.0	2.5	1.6	1.3
2.0	2.2	3.0	2.7	80.0	2.5	1.4	1.1

Examples:	Ca	=	1.82	meq/L			
	Mg	=	0.75	meq/L			
	Na	=	6.70	meq/L			
	Ca	+	Mg	+	Na	=	meq/L
	Ca	+	Mg	=	meq/L		
	CO_3	+	HCO_3	=	meq/L		
	CO_3	=	0.05	meq/L			
	HCO_3	=	0.3	meq/L			
From Table:	pK_2-pk_c	=	2.3				
	p(Ca + Mg)	=	2.8				
	p(Alk)	=	3.5				
			8.6	pHc			