C R O P S E R I E S

IRRIGATION

Irrigation Water Quality Criteria no. 0.506

by T.A. Bauder, R.M. Waskom and J. G. Davis[1]

Quick Facts...

Knowledge of irrigation water quality is critical to understanding management for long-term productivity.

Water with electrical conductivity (EC_w) of only 1.15 dS/m contains approximately 2,000 pounds of salt for every acre foot of water.

In many areas of Colorado, irrigation water quality can influence crop productivity more than soil fertility, hybrid, weed control and other factors.

Salt-affected soils develop from a wide range of factors including: soil type, field slope and drainage, irrigation system type and management, fertilizer and manuring practices, and other soil and water management practices. In Colorado, perhaps the most critical factor in predicting, managing, and reducing salt-affected soils is the quality of irrigation water being used. Besides affecting crop yield and soil physical conditions, irrigation water quality can affect fertility needs, irrigation system performance and longevity, and how the water can be applied. Therefore, knowledge of irrigation water quality is critical to understanding what management changes are necessary for long-term productivity.

Corn plant damaged by saline sprinkler water.

Irrigation Water Quality Criteria

Soil scientists use the following categories to describe irrigation water effects on crop production and soil quality:

- Salinity hazard - total soluble salt content
- Sodium hazard - relative proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions
- pH
- Alkalinity - carbonate and bicarbonate
- Specific ions: chloride (Cl), sulfate (SO_4^{2-}), boron (B), and nitrate-nitrogen (NO_3-N).

Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants.

Salinity Hazard

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC_w). The primary effect of high EC_w water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as EC increases.

Colorado State University

Extension

www.ext.colostate.edu

Table 1. Suggested criteria for irrigation water use based upon conductivity.

Classes of water	Electrical Conductivity
	(dS/m)*
Class 1, Excellent	≤ 0.25
Class 2, Good	0.25 - 0.75
Class 3, Permissible[1]	0.76 - 2.00
Class 4, Doubtful[2]	2.01 - 3.00
Class 5, Unsuitable[2]	≥3.00

*dS/m at 25° C = mmhos/cm

[1]Leaching needed if used.

[2]Good drainage needed and sensitive plants will have difficulty obtaining stands.

The amount of water transpired through a crop is directly related to yield; therefore, irrigation water with high EC_w reduces yield potential (Table 2). Beyond effects on the immediate crop is the long term impact of salt loading through the irrigation water. Water with an EC_w of only 1.15 dS/m contains approximately 2,000 pounds of salt for every acre foot of water. You can use conversion factors in Table 3 to make this calculation for other water EC levels.

Table 2. Potential yield reduction from saline water for selected irrigated crops.[1]

Crop	0%	10%	25%	50%
	% yield reduction			
	EC_w[2]			
Barley	5.3	6.7	8.7	12
Wheat	4.0	4.9	6.4	8.7
Sugarbeet[3]	4.7	5.8	7.5	10
Alfalfa	1.3	2.2	3.6	5.9
Potato	1.1	1.7	2.5	3.9
Corn (grain)	1.1	1.7	2.5	3.9
Corn (silage)	1.2	2.1	3.5	5.7
Onion	0.8	1.2	1.8	2.9
Beans	0.7	1.0	1.5	2.4

[1]Adapted from "Quality of Water for Irrigation." R.S. Ayers. Jour. of the Irrig. and Drain. Div., ASCE. Vol 103, No. IR2, June 1977, p. 140.

[2]EC_w = electrical conductivity of the irrigation water in dS/m at 25°C.

[3]Sensitive during germination. EC_w should not exceed 3 dS/m for garden beets and sugarbeets.

Other terms that laboratories and literature sources use to report salinity hazard are: salts, salinity, electrical conductivity (EC_w), or total dissolved solids (TDS). These terms are all comparable and all quantify the amount of dissolved "salts" (or ions, charged particles) in a water sample. However, TDS is a direct measurement of dissolved ions and EC is an indirect measurement of ions by an electrode.

Although people frequently confuse the term "salinity" with common table salt or sodium chloride (NaCl), EC measures salinity from all the ions dissolved in a sample. This includes negatively charged ions (e.g., Cl^-, NO_3^-) and positively charged ions (e.g., Ca^{++}, Na^+). Another common source of confusion is the variety of unit systems used with EC_w. The preferred unit is deciSiemens per meter (dS/m), however millimhos per centimeter (mmho/cm) and micromhos per centimeter (µmho/cm) are still frequently used. Conversions to help you change between unit systems are provided in Table 3.

Definitions

Abbrev.	*Meaning*
mg/L	*milligrams per liter*
meq/L	*milliequivalents per liter*
ppm	*parts per million*
dS/m	*deciSiemens per meter*
µS/cm	*microSiemens per centimeter*
mmho/cm	*millimhos per centimeter*
TDS	*total dissolved solids*

Table 3. Conversion factors for irrigation water quality laboratory reports.

Component	To Convert	Multiply By	To Obtain
Water nutrient or TDS	mg/L	1.0	ppm
Water salinity hazard	1 dS/m	1.0	1 mmho/cm
Water salinity hazard	1 mmho/cm	1,000	1 µmho/cm
Water salinity hazard	EC_w (dS/m) for EC <5 dS/m	640	TDS (mg/L)
Water salinity hazard	EC_w (dS/m) for EC >5 dS/m	800	TDS (mg/L)
Water NO_3N, SO_4-S, B applied	ppm	0.23	lb per acre inch of water
Irrigation water	acre inch	27,150	gallons of water

Sodium Hazard

While EC_w is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of sodium's specific detrimental effects on soil physical properties. The sodium hazard is typically expressed as the

Table 4. General classification of water sodium hazard based on SAR values.

SAR values	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
≥26	Very high	Generally unsuitable for use.

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

meq/L = mg/L divided by atomic weight of ion divided by ionic charge (Na^{+}=23.0 mg/meq, Ca^{++}=20.0 mg/meq, Mg^{++}=12.15 mg/meq)

sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^{+}) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample. Calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. General classifications of irrigation water based upon SAR values are presented in Table 4.

However, many factors including soil texture, organic matter, crop type, climate, irrigation system and management impact how sodium in irrigation water affects soils. Additionally, at the same SAR, water with low EC_w (salinity) has a greater dispersion potential than water with high EC_w. Sodium in irrigation water can also cause toxicity problems for some crops, especially when sprinkler applied. Crops vary in their susceptibility to this type of damage as shown in Table 5.

Table 5. Susceptibility ranges for crops to foliar injury from saline sprinkler water.

	Na or Cl concentration (mg/L) causing foliar injury			
Na concentration	<46	46-230	231-460	>460
Cl concentration	<175	175-350	351-700	>700
	Apricot	Pepper	Alfalfa	Sugarbeet
	Plum	Potato	Barley	Sunflower
	Tomato	Corn	Sorghum	

Foliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for daytime irrigation. Source: Mass (1990) Crop salt tolerance. In: Agricultural Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp. 262-304.

pH and Alkalinity

The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for irrigation water is from 6.5 to 8.4. Abnormally low pH's are not common in Colorado, but may cause accelerated irrigation system corrosion where they occur. High pH's above 8.5 are often caused by high bicarbonate (HCO_3^{-}) and carbonate (CO_3^{2-}) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. This alkaline water could intensify sodic soil conditions. In these cases, a lab will calculate an adjusted SAR (SAR_{ADJ}) to reflect the increased sodium hazard.

Chloride

Chloride is a common ion in Colorado irrigation waters. Although chloride is essential to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations (Table 6). Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation (Table 6). Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days. Drop nozzles and drag hoses are also recommended when applying any saline irrigation water through a sprinkler system to avoid direct contact with leaf surfaces.

Table 6. Chloride classification of irrigation water.

Chloride (ppm)	Effect on Crops
Below 70	Generally safe for all plants.
70-140	Sensitive plants show injury.
141-350	Moderately tolerant plants show injury.
Above 350	Can cause severe problems.

Chloride tolerance of selected crops. Listing in order of increasing tolerance: (low tolerance) dry bean, onion, carrot, lettuce, pepper, corn, potato, alfalfa, sudangrass, zucchini squash, wheat, sorghum, sugar beet, barley (high tolerance). Source: Mass (1990) Crop Salt Tolerance. *Agricultural Salinity Assessment and Management Manual*. K.K. Tanji (ed.). ASCE, New York. pp 262-304.

Boron

Boron is another element that is essential in low amounts, but toxic at higher concentrations (Table 7). In fact, toxicity can occur on sensitive crops at concentrations less than 1.0 ppm. Colorado soils and irrigation waters contain enough B that additional B fertilizer is not required in most situations. Because B toxicity can occur at such low concentrations, an irrigation water analysis is advised for ground water before applying additional B to crops.

Table 7. Boron sensitivity of selected Colorado plants (B concentration, mg/ L*)

Sensitive		Moderately Sensitive	Moderately Tolerant	Tolerant
0.5-0.75	0.76-1.0	1.1-2.0	2.1-4.0	4.1-6.0
Peach	Wheat	Carrot	Lettuce	Alfalfa
Onion	Barley	Potato	Cabbage	Sugar beet
	Sunflower	Cucumber	Corn	Tomato
	Dry Bean		Oats	

Source: Mass (1987) Salt tolerance of plants. *CRC Handbook of Plant Science in Agriculture*. B.R. Cristie (ed.). CRC Press Inc.

*Maximum concentrations tolerated in soil water or saturation extract without yield or vegetative growth reductions. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

Sulfate

The sulfate ion is a major contributor to salinity in many of Colorado irrigation waters. However, toxicity is rarely a problem, except at very high concentrations where high sulfate may interfere with uptake of other nutrients. As with boron, sulfate in irrigation water has fertility benefits, and irrigation water in Colorado often has enough sulfate for maximum production for most crops. Exceptions are sandy fields with <1 percent organic matter and <10 ppm SO_4-S in irrigation water.

Nitrogen

Nitrogen in irrigation water (N) is largely a fertility issue, and nitrate-nitrogen (NO_3-N) can be a significant N source in the South Platte, San Luis Valley, and parts of the Arkansas River basins. The nitrate ion often occurs at higher concentrations than ammonium in irrigation water. Waters high in N can cause quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables. However, these problems can usually be overcome by good fertilizer and irrigation management. Regardless of the crop, nitrate should be credited toward the fertilizer rate especially when the concentration exceeds 10 ppm NO_3-N (45 ppm NO^{-}_{3}). Table 3 provides conversions from ppm to pounds per acre inch.

[1]*T.A. Bauder, Colorado State University Extension water quality specialist; R.M. Waskom, Extension water resource specialist; and J.G. Davis, Extension soils specialist and professor, soil and crop sciences.*