1999

Water Salinity and Crop Yield

Robert Hill

Richard T. Koenig

Utah State University Extension

electronic publishing

WATER SALINITY AND CROP YIELD

Robert Hill and ***Richard T. Koenig***

May 1999 — ***Utah Water Quality*** — AG-425.3

WATER SALINITY

Irrigated agriculture in Utah depends on adequate, high-quality water supplies. As the level of salt increases in an irrigation source, the quality of that water for plant growth decreases. All irrigation waters contain some salt. In many areas, good quality (low salt and low sodium) water is not available for irrigation, consequently waters containing high levels of salt must be used.

A measure of water salinity that is important for crop yield is Electrical Conductivity (EC). EC is measured in units of deci-siemens per meter, or dS/m. The higher the EC the higher the level of salts in the water and the more difficult it is to grow plants with that water. Increasing salinity affects growth mainly by reducing the plants ability to absorb water.

CROP YIELD RESPONSE TO SALINITY

Considerable study relating crop yield response to waters of different salinities has been summarized in “Water Quality for Agriculture” (1). Generally, crops are classified into four major groups: sensitive, moderately sensitive, moderately tolerant, or tolerant of salinity in irrigation waters (Table 1).

Table 1. Relative salinity tolerance categories for typical Utah crops (listed in order of decreasing tolerance). Salinity tolerance information for additional crops can be obtained from reference 3 at the end of this guide.

Tolerant	Barley, Sugar Beet, Wildrye, Asparagus
Moderately Tolerant	Wheat, Wheat Grass, Zucchini, Beet (red)
Moderately Sensitive	Tomato, Cucumber, Alfalfa, Clover, Corn, Muskmellon, Potato
Sensitive	Onion, Carrot, Bean, Apple, Cherry, Raspberry, Strawberry

Possible yield response of various crops to different levels of salinity is shown in Figure 1. The relationship between ECe (the EC of the soil saturation extract) and ECw (the EC of the irrigation water) is indicated on the graph. When sufficient irrigation water is applied to cause 15% of the water to percolate through the root zone, then the ECe is approximately equal to 1.5 ECw. This deep percolation of water through the root zone is necessary to continue leaching of accumulated salts out of the active root areas. For example, if the ECw is 5 dS/m, then the ECe would be approximately 7.5 dS/m and the expected yield of alfalfa would be only 60% of what it could be with better quality water. This still assumes that 15% of the applied water moves down through the root zone as deep percolation to leach salts out. If the irrigation system design or operation is such that the application rate just meets the plant requirements and there was no leaching, the expected yield would be less than that shown on the graph.

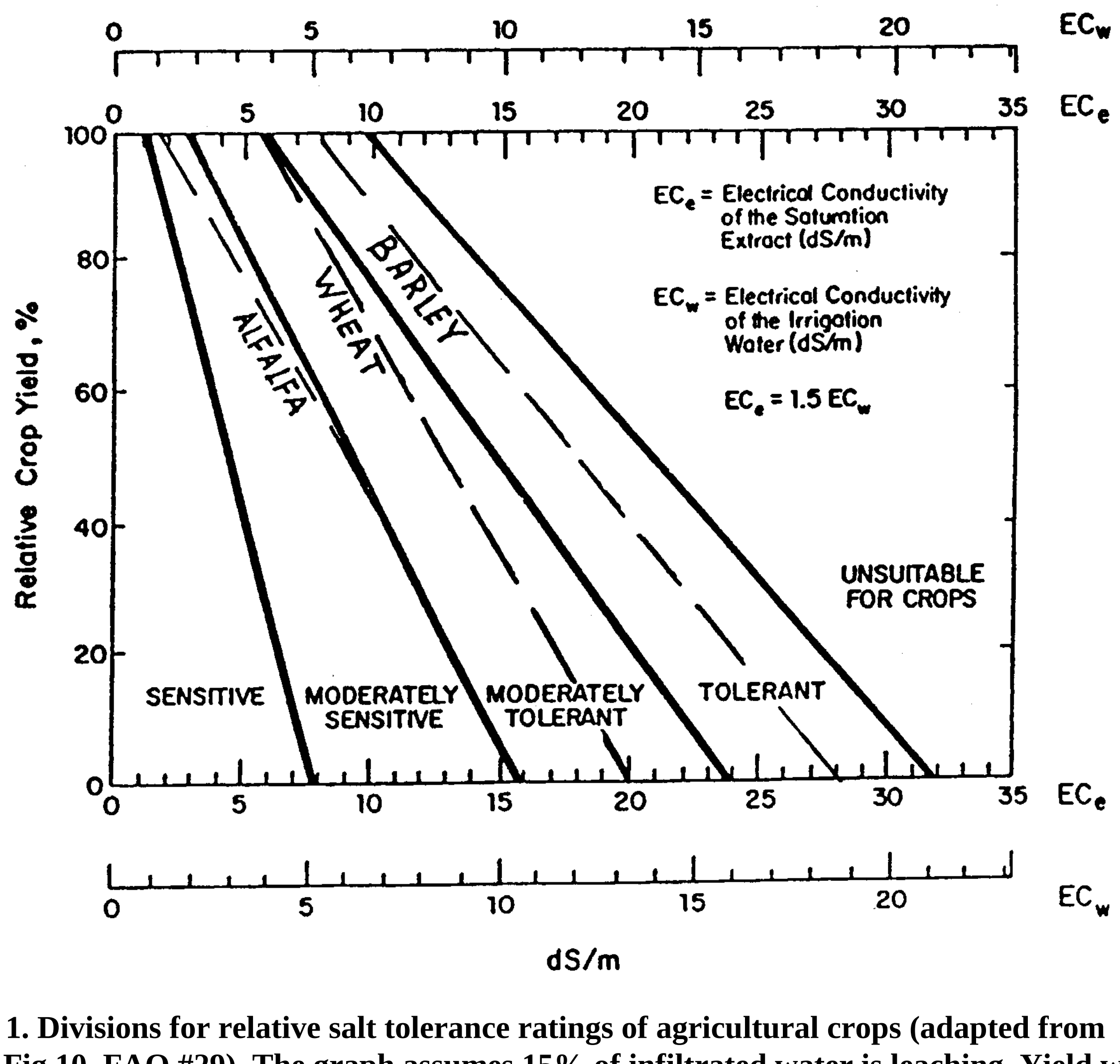

Figure 1. Divisions for relative salt tolerance ratings of agricultural crops (adapted from Fig 10, FAO #29). The graph assumes 15% of infiltrated water is leaching. Yield will be reduced more than the graph shows if leaching is insufficient. Relative yield responses of alfalfa, wheat and barley to salinity are shown by dashed lines.

TYPICAL UTAH IRRIGATION WATER SALINITIES

Water quality samples have been collected at different times and in different locations throughout Utah. James and Jurinak (2) summarized the ECw for various drainage and river systems. An extract of their data is given in Table 2. Also included in Table 2 are the expected yields of alfalfa, barley and wheat if irrigated with waters of this quality (as determined from Figure 1).

There is considerable variability in water salinities around Utah. Most of the streams in Cache Valley are high quality, having ECw values of 0.3 to 0.5 dS/m. The Bear River, particularly the downstream reaches, has higher salinity levels. Generally, as rivers first emerge from mountains along the Wasatch Front, Uintah Basin, and other areas, they have salinities less than 2 dS/m.

In southern Utah, the Virgin River at La Verkin has EC values which vary from 2.7 to 9.1 dS/m depending on the time of year in which the sample was taken. LaVerkin Creek, near LaVerkin, has the highest ECw of any surface stream included in the data. With an ECw of 11.4 dS/m, alfalfa would not grow. Wheat yield would be reduced to about 20% and barley to 55% of their potential yields for well managed conditions in that area.

Also included in Table 2 are well samples from Western Box Elder County. The well at Howell, which is used for center pivot irrigation, has an EC of 4.5 dS/m. This level would reduce alfalfa to 66% and wheat to 95% of possible yields, but would not affect barley yield.

As a general rule, surface water supplies affected by irrigation return flows will have higher conductivity levels later in the summer and early fall. Lower ECw values will be experienced during the spring because of dilution from snow melt.

IRRIGATION WATER ANALYSIS

Irrigation water analysis should include EC, calcium, magnesium, sodium, chloride, carbonate, bicarbonate, sulfate, and boron. The Utah State University Analytical Lab offers an irrigation water quality analysis package including the above parameters for a cost of $15.00 per sample. Contact your County Extension Agent for more information on how to collect a water sample and where to send the sample for analysis.

ESTIMATING LEACHING REQUIREMENTS

Figure 1 is based on standard guidelines that assume the ECe is 1.5 times the ECw and that the leaching fraction is about 0.15 (15%). In actuality, the relationship between ECe and ECw depends on the amount of water added for leaching purposes.

The leaching fraction (or requirement) is the amount of water, in excess of consumptive use, necessary to wash the accumulated soil salts below the root zone:

$$\textit{Leaching Fraction } (LF) = \frac{\textit{Depth of Water Leached Below the Root Zone}}{\textit{Depth of Water Applied at the Surface}} \qquad [1]$$

Table 2. Water quality samples taken in various Utah locations and its estimated effect on relative crop yield.

Location	Date	Electrical Conductivity[a]	%Estimated Relative Yield[b]		
		dS/m	Alfalfa	Barley	Wheat
Surface Streams					
Great Salt Lake drainage,					
B.R. Sage Creek Junction	9-81	.79	100	100	100
B.R. Culter Dam	9-81	.91	100	100	100
B.R. Corinne	9-81	4.01	71	100	100
Logan River, Logan	9-81	.40	100	100	100
Little Bear River, Hyrum Reservoir	8-81	.47	100	100	100
Malad River, Bear River City	8-81	2.01	93	100	100
Ogden River	9-81	.67	100	100	100
Weber River	9-81	.55	100	100	100
Strawberry Reservoir	9-81	.59	100	100	100
Spanish Fork River, Spanish Fork	9-81	.40	100	100	100
Provo River, Provo	9-81	.40	100	100	100
Jordan River, Riverton	9-81	1.74	96	100	100
Sevier River, below Panguitch	9-81	.40	100	100	100
Sevier River, Gunnison	9-81	2.30	90	100	100
Delta Reservoir	9-81	2.14	91	100	100
Chalk Creek, Fillmore	9-81	.40	100	100	100
Beaver River, Beaver	9-81	.29	100	100	100
Parowan Creek	9-81	.41	100	100	100
La Verkin Creek	9-81	11.40	0	55	21
Virgin River, LaVerkin	7-81	9.13	16	75	45
Virgin River, LaVerkin	9-81	2.73	85	100	100
Uintah River Whitrocks	9-81	.06	100	100	100
Uintah River, Randlett	9-81	2.12	92	100	100
Duchesne River, North Fork Tabiona	9-81	.47	100	100	100
Strawberry River, Duchesne	9-81	.74	100	100	100
Duchesne River, Ouray	9-81	1.07	100	100	100
Ashley Creek, Vernal	9-81	2.79	84	100	100
Snowville Creek	9-88	1.84	95	100	100
Fremont River, Bicknell	9-81	.48	100	100	100
Wells in Western Box Elder County					
Rose Ranch Pivot 9	9-88	3.6	76	100	100
Rose Ranch Pivot 17	6-88	5.6	52	97	80
Howell (Mike Weston)	9-88	4.5	66	100	95
Alder Ranch	9-88	3.1	81	100	100

[a]Conductivity of irrigation water (ECw) expressed as dS/m.

[b]Estimated possible yields are shown as a percentage of potential. These estimated yields assume that 15% of infiltrated water is leaching. Yield reduction is (100 - relative yield); example: if the relative yield is 52% then the yield reduction is 48% (48 = 100 - 52).

An estimate of the leaching fraction to maintain a desired crop yield can be made if the irrigation water salinity (ECw) and the soil salinity at the desired crop tolerance level (ECetl) are known (adapted from eq. 9 of FAO 29):

$$LF = \frac{EC_w}{5EC_{etl} - EC_w} \qquad [2]$$

where LF is the minimum leaching fraction necessary for maintaining salts within the crop tolerance soil salinities with above ground irrigation methods, ECw is the salinity of the applied irrigation water (dS/m), and ECetl is the average saturated soil extract salinity (dS/m) tolerated by the crop.

The total annual applied water depth (assuming no precipitation) required to satisfy both ET and leaching is:

$$D_{aw} = \frac{ET}{(1 - LF)} \qquad [3]$$

D_{aw} is the depth of applied water and ET is the consumptive use (both in inches/year). Crop water use (ET) values for locations around Utah are available in Hill (1994). Depending on the timing and the amount, excess natural precipitation that contributes to deep percolation can significantly reduce the leaching requirement from irrigation. Since the crop senses soil salinity as opposed to irrigation water salinity, if extra leaching water is received in the form of natural precipitation, higher salinity irrigation water can be utilized with limited crop losses.

Example. Assume that well water with an EC of 3.1 dS/m was available to irrigate alfalfa. What is the required leaching fraction to maintain yields at 100%? From Figure 1 (or references 1 or 3) the ECetl is 2.0 ds/m or less in order for alfalfa yields to be 100% (no yield loss due to soil salinity). The corresponding leaching fraction from Equation 2 is:

$$LF = \frac{3.1}{5 \times 2.0 - 3.1} = 0.45$$

Expressed as a percent, this means that 45% of the irrigation water must pass through the root zone to provide sufficient salt removal.

If this were an area where the annual crop water use (ET) of alfalfa was 33 inches, then the total annual applied irrigation water depth should be (from Equation 3):

$$D_{aw} = \frac{33}{(1 - 0.45)} = 60 \; inches$$

This is equivalent to 5 acre-feet per acre of infiltrated irrigation water and does not include distribution, conveyance, tailwater surface runoff, or other losses. Additional discussion and more technical details are contained in reference 1, and beginning on page 131 in reference 4, listed at the end of this guide.

REFERENCES

1 Ayers, R. S., and D. W. Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29, Rev. 1, U.N. Rome.

2. James, D.W., and J. J. Jurinak. 1986. Irrigation Resources in Utah: Water Quality versus Soil Salinity, Soil Fertility and the Environment. Res. Bulletin 514. Utah Ag. Exp. Sta., Utah State University, Logan, UT, 84322. December.

3. Kotuby-Amacher, J., R. Koenig, and B. Kitchen. 1997. Salinity and Plant Tolerance. Electronic Publication AG-SO-03, Utah State University Extension, Logan, UT, 84322. July.

4. Hill, R.W. 1994. Consumptive Use of Irrigated Crops in Utah. Utah. Agr. Exp. Sta. Res. Rpt. #145. Utah State University, Logan, UT. This report is available on the Web at: http://nrwrtl.nr.state.ut.us/manuals/consumpt/cfwea.htm

---

Robert W. Hill, Professor and Extension Irrigation Specialist,
Biological and Irrigation Engineering Department,
Utah State University, Logan, UT, 84322-4105.
Rich Koenig, Assistant Professor and Extension Soils Specialist,
Plants, Soils, and Biometeorology Department,
Utah State University, Logan, UT 84322-4820.
