Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT
Irrigation Branch

Salinity and Sodicity Guidelines for Irrigation Water

Studies were conducted at the Lethbridge Research Centre to examine the effects of alternate applications of rain water and saline-sodic irrigation waters ranging from *safe* to *possibly safe* for irrigation. The first study assessed crop yield, soil salinity and soil physical structure with use of irrigation water ranging from *safe* to *possibly safe* according to established salinity and sodicity guidelines. A second study measured changes in infiltration rate and water movement during 11 irrigation cycles with alternate applications of ponded water or sprinkler irrigation with rain water. The studies found water is safe for supplemental irrigation if the electrical conductivity (EC) is less than or equal to 1.0 dS/m and the sodium adsorption ratio (SAR) is less than or equal to 5. If EC is greater than or equal to 2.0 dS/m and/or SAR is greater than or equal to 10, the water is unsuitable for irrigation. Saline-sodic irrigation water with EC between 1.0 to 2.0 dS/m and SAR between 5 to 10 may negatively affect the structural stability of the soil. Soil structural stability should be determined annually if these waters are used for irrigation. With suitable water, irrigating so that 5% of applied water passes through the soil profile will prevent salinization and provide a net reduction in soil salts.

Why Was the Study Conducted?

Most of the water used for irrigation in the South Saskatchewan River Basin of Alberta and Saskatchewan originates as snow melt in the Rocky Mountains and is of good quality, with EC less than 0.5 dS/m and SAR less than 1. However, a few irrigation projects that used saline-sodic waters, (for example, the Verdigris Reservoir and the Etzicom Coulee-Crow Indian Lake projects in Alberta, and the Cadillac Reservoir-Boule Creek projects in Saskatchewan,) have failed due to the adverse impacts of the water on soil structure and crop productivity.

Guidelines for use of saline waters for irrigation are necessary to ensure sustainable irrigation development. Irrigation waters may contain soluble salts in sufficient quantities that plant growth is inhibited and soil productivity is reduced.

Most irrigation water quality guidelines have been developed for arid areas, where crop production is based on the application of saline-sodic water of relatively constant quality. In semi-arid areas, such as southern Alberta, rainfall accounts for up to half the crop water requirements, with the balance supplied by irrigation. On soils irrigated with saline-sodic waters, the low electrolyte concentration of rain water weakens the binding properties of the soil. This contributes to the breakdown of aggregates into fine particles that seal soil pores and reduce infiltration rate and water movement. These effects are highly variable, depending on the physical properties of the soil and on the chemical composition of the saline-sodic water.

Studies were conducted at the Lethbridge Research Centre on a glacial till soil extracted from the vicinity of Verdigris Reservoir to examine the effects of alternate applications of simulated rain water and saline-sodic irrigation waters ranging from *safe* to *possibly safe* for irrigation. The first study assessed changes in soil salinity, soil physical properties, and yield of soft wheat for five crops. A second study measured changes in infiltration rate and water movement during 11 irrigation cycles with ponded water or sprinkler irrigation with simulated rain water. Results were used to assess the irrigation suitability of the saline-sodic waters for the soil examined.

dS/m stands for deci-Siemens per metre, a unit of resistance used to measure electrical conductivity (EC).
EC is a standard way of evaluating soil salinity.

Irrigation water quality guidelines examine the EC and SAR concurrently according to a threshold concept. High salinity promotes stable soil structure, whereas high sodicity results in unstable soil structure. Surface soil stability or instability is described by a threshold curve of EC and SAR, whereby a soil of specified SAR may be more or less stable depending on whether or not the level of EC is sufficient to promote stability. Soils vary widely in their EC-SAR threshold relationships. Hence, water quality guidelines often include a "possibly safe" category to account for variations in sodium stability of soils.

How Was the Study Conducted?

The first study was conducted in a greenhouse using large semi-disturbed soil cores extracted from an area of grassland adjacent to Verdigris Reservoir. These cores were collected in plastic pipe, 0.3 metres in diameter by 1.6 metres long, using a hollow-cylinder auger to cut around the soil and to push the soil into the pipe (Fig. 1).

Cores were randomly arranged within three blocks in a greenhouse and were instrumented to measure soil moisture, sample soil water, and collect drainage water (Fig. 2).

Five crops of soft wheat were grown using alternate applications of irrigation water and distilled water (as simulated rain water). Tests applied sufficient water to result in leaching fractions of 0.05 and 0.10, that is, 5% and 10% of the applied water leached through the soil profile. Irrigation waters ranged from river water (W1) to various saline-sodic waters (W2-W7) considered *safe* or *possibly safe* for irrigation (Table 1).

Aggregate stability, the degree to which soil lumps break down when immersed in water, was determined on samples from the soil surface after each crop. Plant populations, yield, and nutrient composition were also assessed. After the fifth crop, infiltration tests were conducted on the surface soils previously irrigated with alternate applications of saline-sodic and rain water. Soil cores were sub-sampled and EC and SAR were measured for each depth increment.

The second study involved measurements of the rate of water infiltration and movement through semi-disturbed soil cores, 0.15 metres in diameter by 0.30 metres long, extracted from a cultivated field adjacent to the grassland sampling site. The same saline-sodic irrigation waters were alternated with rain (distilled) water. Water was applied in 11 (40 mm) irrigation cycles, allowing for drainage and drying between irrigations. Irrigations were completed by ponding water on the soil surface, in which case mechanical energy or impact on the soil was absent, or by simulating rainfall using a sprinkler system, in which case mechanical energy was present. Pressure head and flow data were collected to determine infiltration and water movement properties.

Figure 1. Drill truck with PVC pipe and hollow-cylinder.

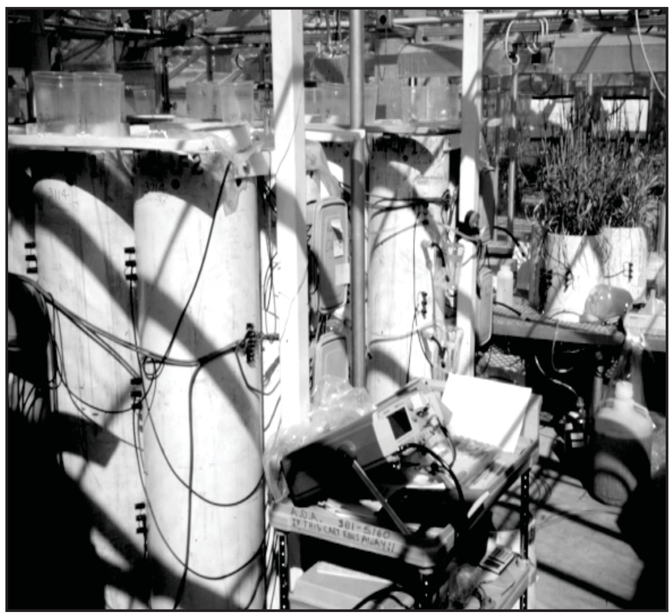

Figure 2. Instrumented soil cores in greenhouse.

Table 1. Mean EC (dS/m) and SAR of irrigation waters used.

Water:	Rain	W1	W2	W3	W4	W5	W6	W7
EC	0.05	0.4	1.0	1.1	2.1	2.1	3.0	3.1
SAR	1.30	1.0	5.0	9.6	11.1	16.0	16.2	21.4

What Did We Learn?

Greenhouse study:

Sodicity (SAR) of the soil profile, monitored by extraction of soil solution, showed that soils irrigated with W1 were maintained at initial low SAR levels in the upper profile and were improved in the lower profile (Fig. 3).

The sodicity of the upper profile increased from crop 1 to crop 5 with the use of progressively more saline-sodic waters. With all waters, SAR of the lower profile improved with successive crops. The increased water application required for a 10% leaching fraction (LF) resulted in greater reduction in SAR of the lower profile. SAR increased in the upper profile with use of more saline-sodic waters. EC and SAR profiles were similar.

Saline-sodic waters had an adverse effect on surface soil structure and infiltration. Surface soils that were granular in structure developed small to massive cracking, that increased in severity with progressively more saline-sodic waters and became more pronounced with successive crops. After five crops, use of W4 to W7 resulted in massive columnar structure with large cracks (Fig. 4). Deterioration of soil structure was directly related to the SAR of the irrigation waters.

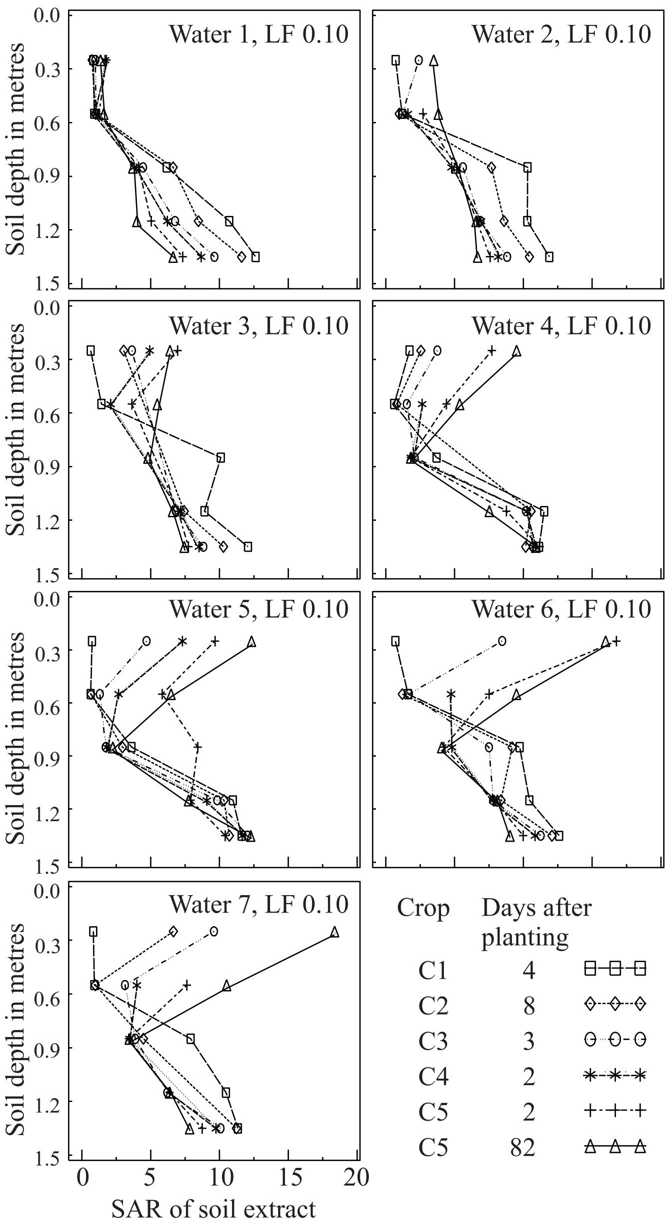

Figure 3. SAR of soil extract during irrigation of five crops with W1 to W7 alternated with rain water.

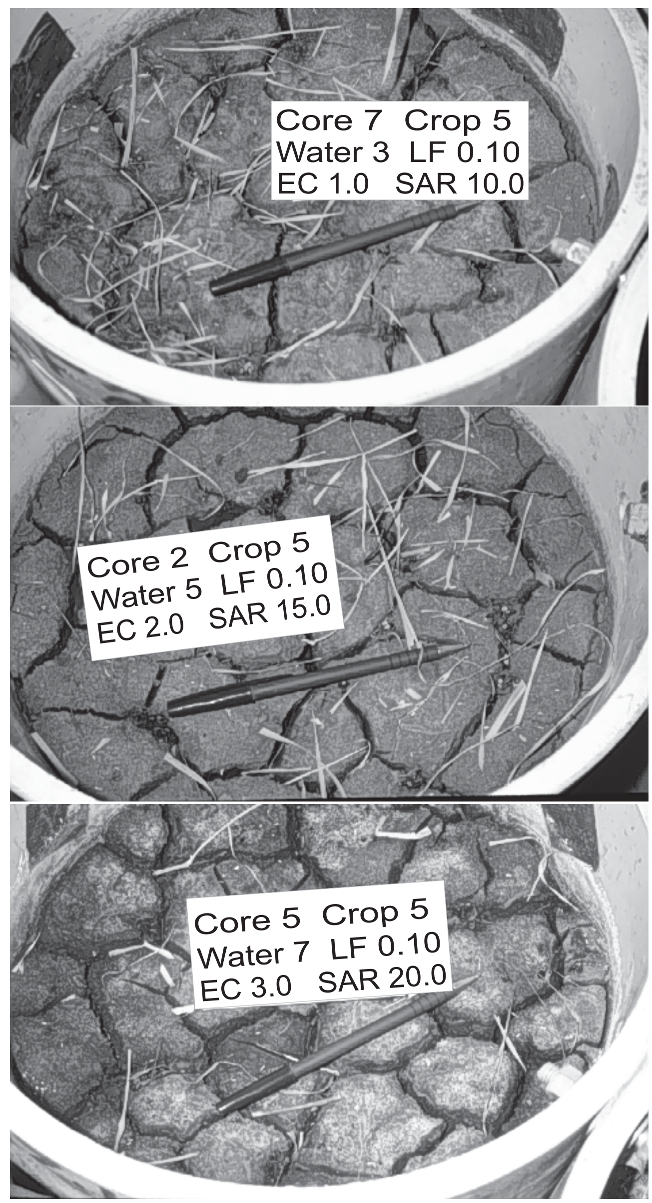

Figure 4. Surface soil structure after irrigation of five crops grown with W3, W5 and W7 irrigation water alternated with rain water.

Soil sodicity profiles after five crops with a 10% leaching fraction (Fig. 5) show that sodicity in the top 0.6 metres of soil generally reflected the sodicity of the irrigation waters. Soil sodicity was significantly greater in the upper 0.3 metres for W3 to W7 compared to W1 and W2. Sodicity profiles for the 5% leaching fraction were similar, but treatment effects were less apparent. Waters of higher EC, but similar SAR, resulted in greater sodicity in the upper soil profile to a depth of 0.45 metres. A 10% leaching fraction resulted in significantly lower SAR at depths of 0.75 metres or more, compared to a 5% leaching fraction.

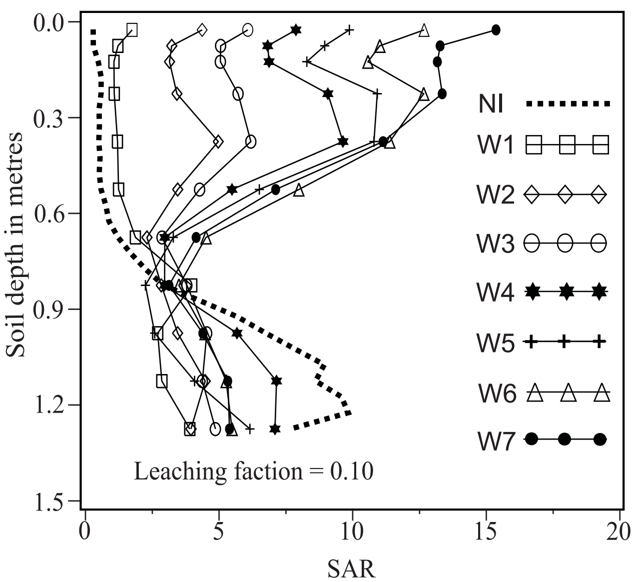

Figure 5. SAR of saturated soil extract after five crops irrigated with W1 to W7 alternated with rain water applications compared to non-irrigated (NI) soil. Crops were irrigated to a 10% LF.

Salinity of irrigation waters (EC) did not affect total dry matter crop yield for the first four crops. In the fifth crop, yields of those crops to which W7 irrigation water had been applied were lower than with W1 and W2. In the third crop, emergence decreased abruptly for treatments W5 to W7 (SAR great than 15). Reduced emergence, which continued into the fourth and fifth crops, was caused by water ponding on the soil surface after post-seeding irrigation with rain water. The ponding that resulted from deteriorated soil structure and reduced infiltration drowned the seeds and prevented germination.

A net reduction in total salt content was observed with irrigation waters of EC 1 dS/m or less (W1 to W3), indicating soil quality would be maintained or improved with their use (Fig. 6).

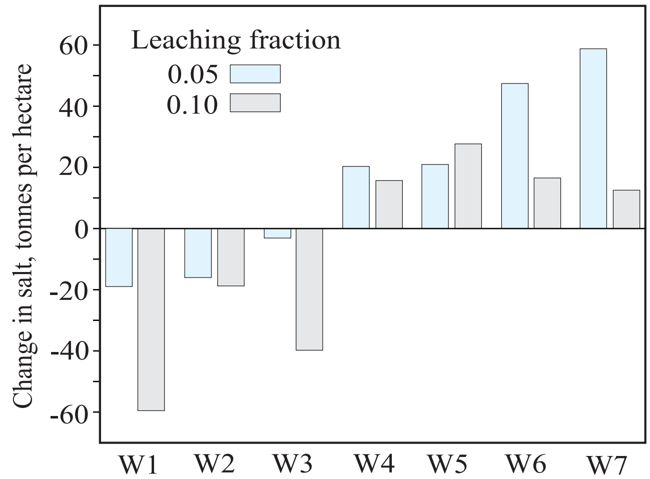

Figure 6. Mean change in salt content (salt added by irrigation minus salt removed through drainage).

Salt removal was greatest with use of a 10% leaching fraction. Use of waters with EC of 2 dS/m or more (W4 to W7) resulted in a net gain in salt content, with a greater increase at the 5% leaching fraction. Salt accumulation was greatest in the top 0.6 metres of soil, indicating soil quality would deteriorate using these waters.

The initial infiltration rate was significantly reduced for all treatments except W1 when simulated rain was used as the infiltrate, and for all waters except W1 and W2 when saline-sodic waters were used (Fig. 7).

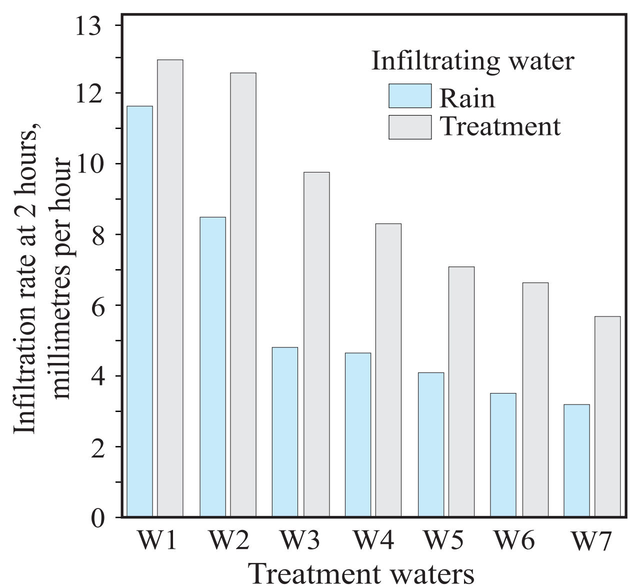

Figure 7. Mean infiltration rate after five crips using alternate applications of simulated rain watres and saline-sodic waters.

Compared to soils irrigated with W1, soils irrigated with W3 incurred a 25% reduction in infiltration rate using W3 irrigation water. This was similar to the reduction observed for soils irrigated with W2 using rain water.

Water movement study:

More detailed studies of water movement in the smaller cores showed that movement through the surface soil (0 to 25-mm depth), rather than infiltration into the surface, was limiting water entry into the soil profile. In ponded tests, infiltration in most cases was higher than the rate of water movement through the soil. In sprinkler tests, infiltration was about 10 times the rate of water movement through the soil. Successive irrigations resulted in lower infiltration rates and reduced water movement.

Infiltration rates for saline-sodic water treatments were not significantly different, regardless of the EC and SAR levels of the irrigation water. Infiltration rates with sprinkler application were about 25 % of those under ponding. With both methods, application of simulated rain water caused a decline in infiltration rate, with a recovery when saline-sodic water was applied.

With simulated rain water in the sprinkler test, and with both rain water and treatment water in the ponded tests, infiltration decreased with time. Infiltration increased with time when saline-sodic waters were applied by sprinkler. This became more evident with increasingly saline-sodic waters and may be the result of increased soil cracking observed with these waters.

Salinity and Sodicity Guidelines for Irrigation

Water suitability for supplemental irrigation was assessed on the basis of a 25 % reduction in a soil physical property or crop yield in relation to river water (Table 2). Total dry matter yield was reduced 25% at an EC of 2.6 dS/m and an SAR of 16. Under ponded conditions, the threshold limits for water movement through the surface soil layer were 1.5 dS/m for EC and 12.0 for SAR. These limits were about half those for sprinkler application. Threshold limits for aggregate stability were lower, with EC of 1.1 and SAR about 11. For the soil examined, the initial infiltration rate and the change in rate of infiltration for rain water were the most sensitive properties for assessing irrigation water suitability. These properties were reduced 25% with EC of 1.0 dS/m and SAR of 5 using rain water, and with EC of about 1.5 dS/m and SAR about 10 using saline-sodic irrigation water.

Table 2. EC and SAR at which a 25% reduction in yield or soil physical property occurred.

Parameter	EC	SAR
Total dry matter crop yield	2.6	16.0
Water movement through soil - sprinkler	3.0	20.3
Water movement through soil - ponding	1.5	12.0
Aggregate stability	1.1	10.8
Initial infiltration rate - irrigation water	1.5	9.8
Initial infiltration rate - rain water	1.0	5.6
Change in rate of infiltration - irrigation water	1.4	9.3
Change in rate of infiltration - rain water	1.0	5.0

Waters considered safe for supplemental irrigation have EC less than or equal to 1.0 dS/m and SAR less than or equal to 5. If EC is greater than or equal to 2.0 dS/m and/or SAR is greater than or equal to 10, the water is considered unsuitable for irrigation. Saline-sodic waters with EC from 1.0 to 2.0 dS/m and SAR from 5 to 10 should be evaluated prior to use for irrigation. Soil structural stability of soils should be assessed annually if these waters are used for irrigation. This is especially important where rainfall provides a significant portion of annual moisture. When using suitable waters, a leaching fraction of 5% was sufficient to prevent salinization and to provide a net reduction in soil salts.

This fact sheet on Salinity and Sodicity Guidelines for Irrigation Water in Alberta is one of a series of information bulletins on agriculture and resource management produced by the Irrigation Branch, Alberta Agriculture, Food and Rural Development.

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This fact sheet was based on research conducted by Gary Buckland, a research scientist with Irrigation Branch, as part of a Ph D degree program at the University of Saskatchewan. For more information on this project, please contact Dennis Mikalson at (403) 381-5145, or call Dennis throught the Alberta Government Riteline, toll-free at 310-0000.

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