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Managing Saline Soils in North Dakota

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Salt Accumulation Processes

Saline soils have salt levels high enough that either crop yields begin to suffer or cropping is impractical. Excessive salts injure plants by disrupting the uptake of water into roots and interfering with the uptake of competitive nutrients. Several factors contribute to the development of saline soils in North Dakota, but a high water table is a prime requirement. Recognizing how and why salts accumulate is the first step in farming profitably on land interspersed with saline soils. Preventing further encroachment of salinity and addressing remediation strategies are other steps.

The weathering of geologic materials has given rise to our present soils, but also produces salts that impact crop growth and yield. Lack of leaching in certain landscapes has kept the salts from leaving. The pattern of saline soils across the state results from years of natural salt redistribution. However, land use practices and rainfall patterns can influence the spread and severity of saline soil. A survey of growers from Hettinger County in 1968 showed that 51 percent of the reported saline soils had appeared within the eight years prior to the survey.

Leaching of salts over time has created shallow saline groundwater in wide areas of the state. Water flows down grade within the soil due to gravity. Where shallow saline groundwater occurs, salts often concentrate at or near the soil surface through capillary rise. In capillary rise, water moves from where the soil is saturated, or nearly so, to drier soil against the force of gravity, much like water moving into a dry sponge from a puddle of water on a floor. Evaporation then dries the soil and "pulls" water by capillary flow from the wet soil zone. Because only pure water evaporates, salts are left behind.

In silt loam soils, this rise can reach eight to nine feet above the water table. Theoretically, a rise of up to 15 feet is possible in a loam or silty clay loam soil (Knuteson et al, 1989). In sandy soils, which have larger pore sizes between soil particles, the pull is less, perhaps reaching 1.5 to 2 feet above the water table (Figure 1). Water movement toward the surface due to

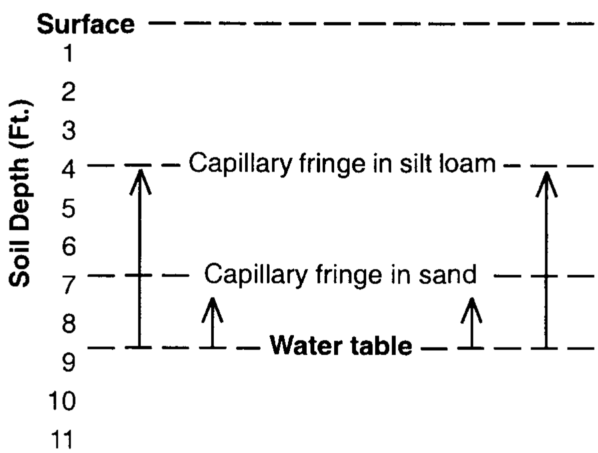

Figure 1. Capillary rise from a water table depends on soil texture. Capillary rise will extend higher in a silt loam, silty clay loam and a very fine sandy loam than in a clay, clay loam or sand.

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capillary rise provides a continuous supply of salts which accumulate in the root zone or at the soil surface when the capillary water evaporates. However, in a clay soil, salinity accumulation is rare, due to the development of strong aggregates which do not allow significant vertical capillary water movement.

Groundwater produces a crop production paradox. Crops can utilize groundwater to supplement precipitation received during the growing season and achieve higher yields. However, groundwater too close to the surface can carry salts as well as water into the crop root zone, causing yield reductions and crop failures. Management of these soils must somehow balance seasonal water needs with salt reduction.

The Nature of North Dakota Salts

The salts most commonly found in concentrations that affect crop growth are sodium sulfate (Na_2SO_4), calcium sulfate (gypsum, $CaSO_4$) , magnesium sulfate (epsom salts, $MgSO_4$), sodium chloride (NaCl), calcium and magnesium chloride. North Dakota's saline soils are usually a mixture of salts, with sulfates being the most dominant form.

Most North Dakota salinity is due to calcium sulfate, magnesium sulfate and sodium sulfate. Chloride salts are also found in groundwater which has passed through or resides in geological materials with significant chloride in their solid matrix. Sodium chloride is the dominant salt in the saline soils of eastern Grand Forks County. Artesian flow from geologic deposits with significant sodium and chloride sources has added sodium chloride to shallow groundwater in that area. Saline soils develop where the evaporation exceeds the growing season rainfall, and local landscape features accumulate seasonal runoff to form a water table which at some point rises to less than six feet below the soil surface. The Northern Great Plains of the United States and Canada have vast areas that meet these criteria and where saline soils are common.

Where Do Salts Accumulate?

Figures 2a, 3 and 4 provide examples of where salts are commonly found in North Dakota landscapes due to shallow saline groundwater. It is common for potholes and slow-moving natural drains to have an accumulation, as shown in Figure 2a, a short distance from the water's edge. In this example, water can move significant distances laterally over a long period of time, flushing the soil of salts as it moves and concentrating these salts at the maximum depth above the water table where the capillary water rises and then evaporates. This condition is also common along road ditches, field ditches and next to sewage lagoons.

Figure 3 shows surface salt accumulation due to seasonally wet soils. A feature found in seasonally wet

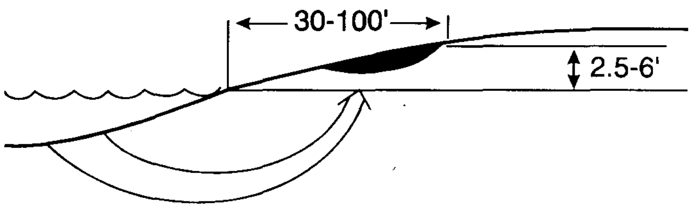

Figure 2a. Saline soil development near shallow streams, road ditches and sewage lagoons.

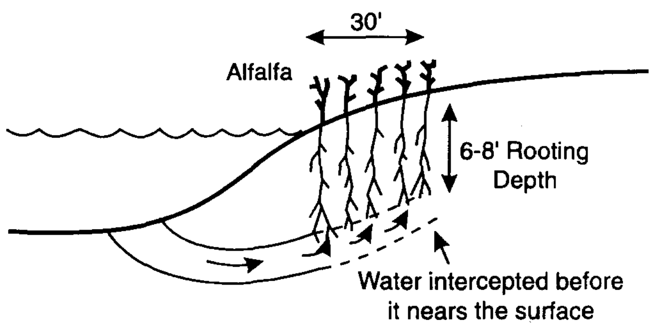

Figure 2b. Use of a 30-foot alfalfa strip along borders of shallow stream, road ditch or sewage lagoon prevents fringe salt deposition.

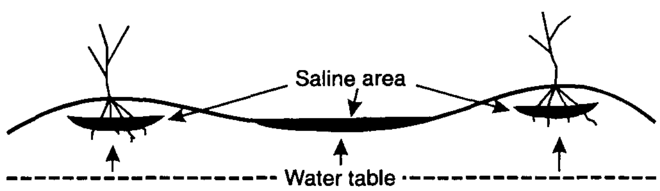

Figure 3. Saline development in a nearly level landscape with a shallow, saline water table. Continuous cropping will help decrease development.

saline soils is a relatively low area with white, crusty, salty material, surrounded with sparse crop growth and a sharp boundary where crops grow reasonably well. It is common when examining soil in these low areas to see small pockets of crystalline salts in the plow layer. A subsoil sample beneath the fringe crop plants surrounding the bare area often reveals salt crystals there, also. However, crops in the depression edge usually grow normally. In this example, the crops rooting into the capillary fringe have enough water, but, through drying of the soil around the roots, salts accumulate in the soil at the top of the capillary fringe, somewhere below the surface.

Figure 4 shows a condition in a subtly undulating landscape with a silty clay loam or silty clay texture. This landscape usually would have an elevation difference of only six to eight inches from top to bottom. Rainfall runs off the slowly permeable clay into the microrelief depressions in-between the higher elevations. Water then leaches out the salts in the depressions. Groundwater containing salt rises through capillary flow to the highest soil surface.

In addition to these conditions, North Dakota also has large areas where a shallow water table lies under a relatively flat soil surface. Subsoil salt accumulation in these areas is widespread. High rainfall years raise water table levels, which bring salts to or near the surface, adversely affecting crop growth. Following drought and a lower water table, rains leach the salts to a lower depth. As the salts are washed lower, the salt concentration in the rooting zone is decreased and crop growth improves.

Another serious saline soil problem, especially in hillier regions of North Dakota, is saline seeps. Saline seeps form in the landscape when water percolates from higher elevations, reaches a zone of vertical discontinuity, usually a relatively impermeable layer such as loam material over clay, or a coal seam (Figure 5). Water will then move laterally, exiting at the side or bottom of the hill. In dry years, these areas are usually not saline. In wet years, they appear as salty areas in the side slopes and bottoms of hills.

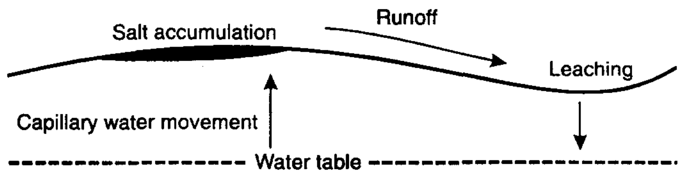

Figure 4. Saline development on a high clay content, subtly undulating landscape. Salt accumulates on high clay content ridges, while the low spots are leached of salts. Continuous cropping will help lower water table and stop salinity development.

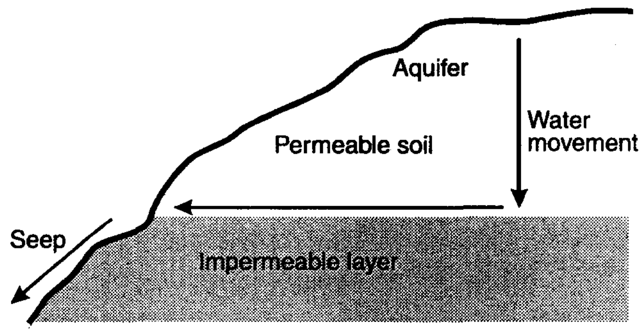

Figure 5. Saline seep development.

Saline Soil Management

Tile drainage

In parts of the world which have natural, well-developed drainage systems of rivers and streams, the simplest way to solve a saline soil problem is to install tile drainage in the problem fields, leaching low-salt water through the soil profile, and thereby allowing the salts to be carried away from the field through tile lines and into drainage canals or natural waterways. Until recently, there has been little interest in tile drainage in North Dakota. However, some tile has been installed in the Red River Valley, and salinity has been reduced as a result in some fields. When investigating the feasibility of installing tile drainage, it is important to consider the outlet. The water must flow to some natural drainage, such as a river or stream. It should not be dumped into the neighbor's field. Working with USDA-NRCS (Natural Resource Conservation Service) and the North Dakota Water Commission should be a part of the planning and implementation process. Mitigation of affected wetland areas may need to be considered.

If drainage is physically possible, tile construction within fields is expensive. A tile system in a loam soil may require parallel tile lines about 200 feet apart, with a cost of approximately $500 per acre or more. Tile systems in silty clay loam, clay loams and clay textured soils are even more expensive due to the need for closer tile spacing. For some, the cost of tile drains will appear justified, given the increase in salinity during wet years, and crop losses due to excessive soil wetness and increased salinity levels. Investing in tile drainage, however, is a gamble, because a significant portion of years during a farming career will be dry in this region.

Some consideration for drainage should be made in irrigated lands, particularly if soils are rated conditional due to drainage and salinity hazard. In western irrigated states, leaching soils periodically with large volumes of additional irrigation water following harvest drains away the buildup of salts in conditional soils and prepares the land for seeding the following year. Irrigation development on western lands is often conducted with as much consideration to tile drainage as for the irrigation system itself. Salinity and sodicity management are both controlled and managed with an irrigation/drainage system.

Tillage and seedbed preparation

Stand establishment is a critical crop yield factor for all crops, especially in saline soils. Salts affect germination and emergence in a manner similar to seedbed drying. Stand loss from poor emergence is directly proportional to soil salt concentrations above a relatively low threshold level. Many crops are much more sensitive to salt levels as a germinating seed and seedling than as established plants (Table 1). Once a plant is established, it is normally more tolerant of higher salt levels.

Salt levels in a seedbed can often be managed to acceptable limits. Seeding of spring-seeded crops on saline soils should be conducted to take advantage of the leaching potential of spring rains. One inch of rainfall can reduce salt concentrations by 50 percent in the one- to two-inch depth seedbed required for most crops grown in North Dakota. Lowering salt concentration in the seed planting zone can provide a dramatic increase in germination and seedling survival.

No-till or reduced/minimum tillage systems which use shallow tillage are recommended for seedbed preparation in saline soils. Salts leached away by winter snow melt and spring rains can be returned to the surface by deep spring tillage. Fall tillage should also be evaluated on the basis of spring seedbed preparation needs and relative salt levels in the tillage depth. Most deep tillage operations on saline land unnecessarily increase surface salt concentrations.

Soil testing for salinity

Soil areas that are severely affected by salts often have a bright white, crusty appearance when dry. The severity of the saline area usually extends well beyond the obvious area. In areas lacking a surface crust or obvious vegetation loss, salts are dissolved in soil water and cannot be seen. Therefore, the extent of the problem can only be identified with a soil test.

Soil testing laboratories use the electrical conductivity (EC_e) of a soil extract to measure salt concentrations. Laboratories use strict procedures and check samples to ensure precision and accuracy of the test results. Personal handheld conductivity sensors are available through farm supply catalogues which may be less accurate than a lab, but with calibration would provide some indicator of the presence and severity of soil salinity to individual farmers and crop consultants.

There are also larger tools for spatial mapping available (Figure 6), such as the EM-38 (Geonics, Ltd, Missis-

Table 1. Relative sensitivity to salts of germinating and established crop plants.

Crop	Salt tolerance of germinating plants	Salt tolerance of established plants
Alfalfa	low	low-medium
Barley	high	high
Corn	medium	low-medium
Dry bean	very low	very low
Sugarbeet	low	high
Wheat	medium	medium-high

Figure 6. Veris conductivity sensor (top), EM-38 in use. (Norm Procnow and Hal Weiser, USDA-NRCS, Jamestown, N.D.)

sauga, Ont.) and pull behind soil-contact sensors such as the Veris EC sensor (Veris, Inc., Salina, Kan.). These can be used to make field measurements quickly and help define saline area boundaries. These sensors will give relative levels of salinity, but the readings cannot be translated into laboratory EC values. Directed measurements are important, because when a composite soil sample is taken to represent a field, areas of high and low salinity are mixed and results may paint an unrepresentative picture of salinity status.

Measurements should be taken within the suspected saline area, some just outside the most affected land, and another at some distance surrounding the area in order to properly map the field. Field EC_e levels can be extremely variable within short distances. Knowing what the salinity patterns are in the field can improve a salinity management strategy.

Electrical conductivity is a low-cost analysis. The results are either reported as decisiemens/meter (dS/m) or as millimhos/cm (mmhos/cm). One dS/m equals one mmoh/cm, so the terms are equivalent. Data, charts and papers can be found which use both terms.

Laboratories measure EC_e on different soil to water extracts because of their convenience to the laboratory. The most common commercial laboratory measurements are made on extracts from either a saturated paste or a 1:1 by weight soil-to-water slurry. The saturated paste extraction is a more precise method used by the scientific community, but it is time-consuming and expensive. The 1:1 soil:water slurry method is a simple, rapid, low-cost and excellent procedure for screening problem soil sites and is the procedure used by the NDSU Soil Testing Laboratory.

Results can roughly be converted back and forth from a 1:1 slurry to a saturated paste, using the following formulas in Table 2. These formulas are not well calibrated and are only included as a rough guide for interpreting data from the literature to data seen on most commercial soil tests.

Table 2. General conversion from 1:1 soil:water slurry used by many commercial labs and the saturated paste extract method used in research applications.
x = Ec_e of 1:1 soil:water slurry
y = Ec_e of saturated paste extract

	Soil Texture	
Coarse	**Medium**	**Fine**
x = 3.01y - 0.06	x = 3.01y - 0.77	x = 2.96y - 0.95
y = 0.33x + 0.06	y = 0.33x + 0.77	y = 0.375x + 0.97

Crop tolerance

Crops have different tolerance levels for salt concentrations. All crops have a maximum salt level they can tolerate without a yield loss. Salt levels above a crop's maximum tolerance level sharply reduce yields.

The generally accepted soil salinity ratings for field crops, pasture and hay grasses and vegetables are shown in Tables 3 through 5, respectively. The tables show tolerance levels developed using the saturated paste extract, and also include estimates of thresholds using the 1:1 soil:water slurry method. The estimated effects of common crop yields on soils of increasing EC are shown in Table 6. When reading the tables, it is important to realize that the values do not come from an average of hundreds of cultivars of each crop or plant. The values are related to the limited scope of one to several experiments under one to several environments. Our experience in North Dakota shows that there is a wide range of intolerance to tolerance to salinity in most crops.

The tables show that certain crops such as dry bean need to be grown in fields with lower salinity, and that profitability in fields with higher EC would increase with more highly tolerant crops. When fields of intermediate to higher salinity (greater than EC 1.0 mmoh/cm, generally) are encountered, discussing the higher salt conditions with a knowledgeable seeds person and obtaining a higher yielding, more salt tolerant variety would be wise.

The tables do not account for the presence of other stresses. In soybean, for example, the tables represent the tolerance of that crop to salts in the absence of iron chlorosis. However, Red River Valley studies (Franzen and Richardson, 2000) show that when chlorosis is present, the threshold salinity is close to EC 1.0 . The table values, therefore are not predictors of what will happen in the field. They should be considered as representative of differences between crops, but actual responses in the field will be modified for better or worse by environmental and management related stresses or improvements from "normal" conditions.

Lower the water table and lower salinity risks

The key to managing saline soils is to control the flow of saline water into the crop root zone. When the source of saline water is a shallow water table, the management tool is to lower the water table. Since drainage is not a common option in North Dakota, the solution is to continuously crop, using late-maturing, deep-rooted crops in the rotation.

A crucial element in successful salt reduction in a continuously cropped system is to eliminate bare or black summer fallow. Water use efficiency of fallow ranged from only 0 to 18 percent of rainfall during a five-year study. The researchers found that some water evaporated, but some contributed to ground-water below four feet in depth. If the soil profile is dry enough, however, the loss to groundwater is minimal and certain soils would retain more infiltrated water in the upper four feet in the spring.

The study found that fallowing in a loam-textured soil when soil moisture before planting was less than four inches in the top four feet did not contribute excess water to groundwater. Soil moisture levels of four inches of available water in the upper four feet in a loam soil is about 50 percent of field capacity. Extending this principle to a sandy loam would not be appropriate, since the maximum water holding capacity of coarser soils are often not much more than four inches, so significant rainfall is rapidly moved to deeper depths.

It would be rare to have soil moisture levels low enough in the spring that fallow would not result in seasonal losses of added precipitation to groundwater. When spring moisture levels are sufficient for crop production, the chances of salts reaching the rooting zone are very high and fallow should not be used.

Table 3. Crop salt tolerance ratings, row crops and grains, annual forages.

	Threshold Salinity		% Yield decrease	Ec_e at 70% yield	Relative tolerance*				
Crop	1:1 soil:water slurry, dS/m**	Saturated paste method, dS/m	% per dS/m saturated paste	saturated paste dS/m	S	MS	MT	T	Source
Alfalfa	1.4	2.0	7.3	6.1		X			Bernstein & Francois, 1973
Barley	3.4	8.0	5.0	14.0				X	Hassan et al., 1970a
Beans, dry	1.1	1.0	19.0	2.6	X				Osawa, 1965
Canola (*rapa*)	4.0	9.7	14.0	11.8				X	Francois, 1994
Canola (*napus*)	4.4	11.0	13.0	13.3				X	Francois, 1994
Chickpea	-	-	-	-		X			Manchanda & Sharma, 1989
Corn	1.3	1.7	12.0	4.2		X			Hassan et al., 1970b
Crambe	1.4	2.0	6.5	6.6		X			Francois & Kleiman, 1990
Flax	1.3	1.7	12.0	4.2		X			Hayward & Spurr, 1944
Millet	-	-	-	-		X			Maas & Grattan, 1999
Oat	-	-	-	-			X		US Salinity Lab, 1954
Potato	1.3	1.5	14.0	3.7		X			Bernstein et al., 1951
Rye	4.5	11.4	10.8	14.2				X	Francois, 1989
Safflower	-	-	-	-			X		Francois & Bernstein, 1964
Sorghum	3.0	6.8	16.0	8.7			X		Francois et al., 1984
Soybean	2.4	5.0	20.0	6.5			X		Bernstein & Ogata, 1966
Sudangrass	1.7	2.8	4.3	9.8			X		Bower et al., 1970
Sugarbeet	3.1	7.0	5.9	12.0				X	Bower et al., 1954
Sunflower	2.4	4.8	5.0	10.8			X		Francois, 1996
Wheat	2.8	6.0	7.1	10.2			X		Asana & Kal, 1965
Wheat, semidwarf	3.6	8.6	3.0	18.6				X	Francois et al., 1986
Wheat, durum	2.7	5.9	3.8	13.8				X	Francois et al., 1986

* S = sensitive, MS = moderately sensitive, MT = moderately tolerant, T = tolerant
**estimated value based on a medium soil

A late-maturing, deep-rooted crop with salt tolerance would be a good choice to help lower the water table. Deep-rooted, salt-tolerant crops can utilize saline groundwater. Figure 7 shows that crops can root deep to utilize saline groundwater, depending on the soil texture.

Several studies have shown that alfalfa is an excellent choice to help lower the water table. Alfalfa should be used as a part of a rotation or as a permanent water barrier when it is necessary to control the flow of salt water from one soil to another. Along ditches, potholes and intermittent streams, a 30-foot strip of alfalfa will use enough water that salts are kept from approaching the surface (Figure 2b). In situations where the water table is too high, alfalfa will lower it better than any other crop. In recharge areas, alfalfa can use a large amount of water before it has a chance to discharge farther down slope.

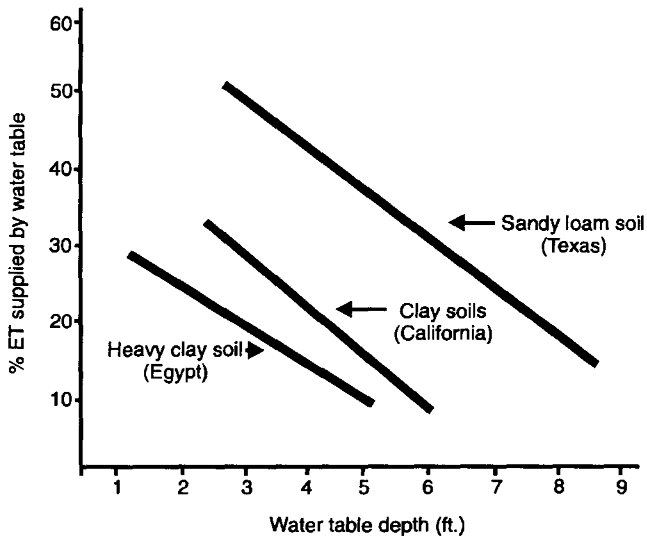

Figure 7. Evapotranspiration supplied by a saline water table as affected by water table depth. (Gismer and Gates, 1988).

Table 4. Crop salt tolerance ratings, pasture and hay grasses.

Crop	Threshold Salinity: 1:1 soil:water slurry, dS/m**	Threshold Salinity: Saturated paste method, dS/m	% Yield decrease: % per dS/m saturated paste	Ec_e at 70% yield: saturated paste dS/m	Relative tolerance*: S	MS	MT	T	Source
Alkaligrass nuttal	-	-	-	-				X	US Salinity Lab, 1954
Alkali sacton	-	-	-	-				X	US Salinity Lab, 1954
Brome, smooth	-	-	-	-			X		McElgunn & Lawrence, 1973
Fescue, tall	-	-	-	-			X		Bower et al., 1970
Grama, blue	-	-	-	-		X			US Salinity Lab, 1954
Ryegrass, perennial	2.6	5.6	7.6	6.5			X		Brown & Bernstein, 1953
Timothy	-	-	-	-		X			Saini, 1972
Wheatgrass, fairway crested	3.2	7.5	6.9	11.8				X	McElgunn & Lawrence, 1973
Wheatgrass, intermediate	-	-	-	-			X		Dewey, 1960
Wheatgrass, slender	-	-	-	-			X		McElgunn & Lawrence, 1973
Wheatgrass, tall	3.2	7.5	4.2	14.6				X	Bernstein & Ford, 1958
Wheatgrass, western	-	-	-	-			X		US Salinity Lab, 1954
Wild rye, beardless	1.7	2.7	6.0	7.7			X		Brown & Bernstein, 1953
Wild rye, canadian	4.5	11.4	10.8	14.2			X		US Salinity Lab, 1954
Wild rye, russion	-	-	-	-				X	McElgunn & Lawrence, 1973

* S = Sensitive, MS = Moderately sensitive, MT = Moderately tolerant, T = tolerant
**estimated value based on a medium soil

Table 5. Crop salt tolerance ratings, vegetables.

Crop	Threshold Salinity		% Yield decrease	Ec_e at 70% yield	Relative tolerance*				Source
	1:1 soil:water slurry, dS/m**	Saturated paste method, dS/m	% per dS/m saturated paste	saturated paste dS/m	S	MS	MT	T	
Bean	1.1	1.0	19.0	2.6	X				Osawa, 1965
Cabbage	1.4	1.8	9.7	4.9		X			Bernstein & Ayers, 1949
Carrot	1.1	1.0	14.0	3.1	X				Bernstein et al., 1964
Corn, sweet	1.3	1.7	12.0	4.2		X			Bernstein & Ayers, 1949
Cucumber	1.6	2.5	13.0	4.8		X			Ploagman & Biehuizen, 1970
Lettuce	1.2	1.3	13.0	3.6		X			Bernstein et al., 1974
Muskmelon	1.1	1.0	8.4	4.6		X			Shannon & Francois, 1978
Onion	1.2	1.2	16.0	3.1	X				Hoffman & Rawlins, 1971
Pea	1.9	3.4	10.6	6.2		X			Cerdá et al., 1982
Pepper	1.3	1.5	14.0	3.6		X			Osawa, 1965
Pumpkin	-	-	-	-		X			Maas & Grattan, 1999
Radish	1.2	1.2	13.0	3.5		X			Hoffman & Rawlins, 1971
Squash, zucchini	2.4	4.9	10.5	7.8			X		Graifenberg et al., 1996
Strawberry	1.1	1.0	33.0	1.9	X				Osawa, 1965
Sweet potato	1.3	1.5	11.0	4.2		X			Greig & Smith, 1962
Tomato	1.6	2.5	9.9	5.5		X			Bierhuizen & Ploagman, 1967
Turnip	1.1	0.9	9.0	4.2		X			Francois, 1984
Watermelon	-	-	-	-		X			deForges, 1970

* S = sensitive, MS = moderately sensitive, MT = moderately tolerant, T = tolerant
**estimated value based on a medium soil

Table 6. Relative crop yields at increasing levels of soil EC.

Crop	Electrical conductivity, Ec_e dS/m, saturated paste method											
	2	4	6	8	10	12	14	16	18	20	22	24
	Percent (%) of maximum yield potential											
Alfalfa	100	85	71	56	42	27	12	0	0	0	0	0
Barley	100	100	100	100	90	80	70	60	50	40	30	20
Canola (*napus*)	100	100	100	100	100	87	61	35	9	0	0	0
Corn	96	72	48	24	0	0	0	0	0	0	0	0
Dry bean	81	43	5	0	0	0	0	0	0	0	0	0
Flax	96	72	48	24	0	0	0	0	0	0	0	0
Soybean	100	100	90	50	10	0	0	0	0	0	0	0
Sugarbeet	100	100	100	97	85	73	61	49	37	25	13	0
Sunflower	100	100	97	87	77	67	57	47	37	27	17	7
Wheat, durum	100	100	100	96	88	80	72	64	56	48	40	32
Wheat, semidwarf	100	100	100	92	84	76	68	60	52	44	36	28

Other possible rotational crops are sunflower and safflower. However, they are not as good as alfalfa in using water because of their annual growth habit. Sweet clover would be an excellent green manure crop which would help on fallow by lowering the water table and supplying nitrogen for the next crop. Water use by sweet clover is often great enough to reduce yields the following season. Proper management will reduce this risk. If green manures are used, shallow tillage instead of plowing is recommended, so that salts are not returned to the surface.

There may be years when, despite the best water table management, excessive rainfall could raise the water table close to the surface. However, the chances of this event would be greatly reduced if the water table was lower initially. Lowering the water table should be viewed as a long-term management tool, and not a quick nor permanent renovation technique.

Late-maturing crops with deep rooting properties are important for saline soil management for the following reasons:

1. Late-maturing crops provide a mulching soil cover until frost, reducing the potential for late summer and early fall surface evaporation.
2. Deep-rooted crops leave the soil drier at deeper depths going into the winter, increasing the potential for salts to leach away from the soil surface.
3. Deep-rooted crops can use more water at the capillary water boundary, preventing further upward movement.

In a recharge area, which is the source of the water that carries salts to a discharge site, a perennial, deep-rooted crop is best at limiting discharge. The next choice is a deep-rooted, long season annual. The third choice is any annual crop.

The following crops are ranked by their potential contribution to limiting salt water discharge from a recharge area: alfalfa>sweet clover>sunflower, safflower, sugarbeet>barley, wheat, soybean, durum wheat and canola.

A crop rotation could be designed so that a combination of perennial and annual crops could be used to diversify the system to meet goals of improved soil quality and profitability. The most important point, no matter what cropping system is used, is to continuously crop the recharge area with something green for as long a period as possible.

In the discharge area, a salt-tolerant crop will be the only crop which can be grown. A list of crops and general crop tolerances are given in Tables 3-5. These lists are very general. There may be situations when the most salt-tolerant crops do not perform well in these areas. There may be other situations in which sensitive crops do quite well. There will also be differences between varieties of the same crop. Information concerning the salt tolerance of specific varieties should be obtained from a commercial seed source before making a selection. It will also be important to note Table 1, which shows that there are differences in the ability of crops to tolerate salt at germination and later on. Sugarbeet, once established, is one of the most salt-tolerant crops available, but it is very sensitive to salt levels at germination.

Managing Sodic Soils

Many saline soils in North Dakota also have elevated levels of sodium. High levels of sodium restrict water-holding capacity in two ways. First, sodium prevents soil clay particles from gathering together into small aggregates. This process of gathering together is called flocculation. Flocculation allows water to penetrate between the groups of soil particles and provide moisture at deeper depths. When sodium levels are high enough to prevent flocculation, the individual clay particles overlap each other randomly during wet conditions, preventing water penetration through the high sodium layer.

Secondly, when the soil dries out, areas within high sodium soils form hard massive structures which look like round-topped columns. These columns do not allow roots to penetrate, so the only water and nutrients which are available to plant roots come from the small surface area surrounding these structures. The plants are therefore allowed only a small percentage of the total possible volume of soil in which to grow.

Areas of high sodium in glacial till soils can be suspected when soil pH is greater than 8.4. However, many high sodium soils in southwest North Dakota have pH values less than 6 and may tend to be even more acidic in parts of some fields. Suspicions of sodium affected soils can be confirmed by requesting a sodium soil test, along with calcium and magnesium. The concentrations of all three elements can be used to calculate the SAR (sodium absorption ratio) or the ESP (exchangeable sodium percentage), which indicates the level of sodicity present. Most laboratories equipped to analyze for potassium are also equipped to analyze for sodium.

The spread of high sodium areas can be checked by following the same management plan as for any salt problem. Decreasing the level of sodium may be much more difficult, however. Because of the restriction of water movement within the soil, leaching is more difficult.

Use of gypsum as a sodium remediation amendment

If high levels of gypsum are present in the soils with high sodium, addition of gypsum will not help replace sodium in the soil. In these soils, deep tillage may help to mix the gypsum already present in the soil with the sodium bearing soil horizons. If the soils do not already contain gypsum, addition of gypsum will replace sodium with calcium in the profile. Amounts of gypsum required to amend the upper foot of soil may be four-eight tons/ acre. The material needs to be mixed into the layer of soil which needs the amendment. In order for the application to work, sulfate should not be the dominant ion in the soil. If sulfate levels are low, or other anions such as chloride are proportionally high, then gypsum amendments will be able to dissolve and replace sodium ions. For the application to be successful, it is important that good drainage be present. Drainage can be either natural or tile. Water is also needed to flush the sodium out of the soil once the application is made. Without good drainage, any amendment will not work as needed.

In soils with high sulfate levels and relatively low levels of chloride, calcium chloride will perform an even faster remediation than gypsum at about 85 percent of the gypsum rate. Calcium chloride is more soluble than gypsum, therefore it needs less water to become active.

Summary of Saline Soil Management Tools

1. Soil test for salinity levels and the extent of the problem in each field.
2. Select the right crop and variety for the situation.
3. Use shallow tillage.
4. Schedule seeding in saline areas when salt levels are lowest, from snowmelt or spring rains.
5. Do not fallow if available water in the top four feet of soil is sufficient to grow a minimal crop, or if the soil texture is sandy loam or coarser.
6. Use long growing season, deep rooted crops to control the water table depth.

Summary of Sodic Soil Management Tools

1. Soil test of sodium, have the laboratory determine the sodium index (SAR or ESP).
2. Determine if gypsum is present at deeper soil layers, and if so, deep tillage may be helpful.
3. Improve drainage within the site.
4. If sulfates are low, gypsum applications from four-eight tons per acre combined with adequate soil mixing and drainage would improve the soil.
5. If sulfates are high, calcium chloride, at rates about 85 percent of gypsum requirement, combined with adequate soil mixing and drainage would improve the soil.
6. If amendments and drainage are cost-prohibitive, growing more drought tolerant crops, more timely tillage to avoid making clods and attention to inputs would improve profitability. If areas of sodium are extensive, the field may be better off in pasture, with drought tolerant, sodium/salt tolerant grasses.

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