

DETERMINING THE ECONOMIC RESPONSE OF SODIC SOILS TO REMEDIATION BY GYPSUM, ELEMENTAL SULFUR AND VERSALIME IN NORTHEAST NORTH DAKOTA ON TILED FIELDS

By

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INTRODUCTION:

Saline and sodic soils have been reported in North Dakota since the 1960s. NDSU Extension Bulletin No. 2 reported more than 1 million acres affected by high salt levels, whereas, more than 2 million acres are said to have excessive levels of sodium (Salt Affected Problem Soils in North Dakota, Their Properties and Management by Gordon A. Johnsgard, reprinted in 1974). This is a result of high salt and sodium levels in the soil parent material and the underlying sodium-rich shale present in the bedrock below the soil sediments. Rising groundwater levels and resulting capillary rise of soil water leads to the accumulation of excessive soluble salts (salinity) and sodium (sodicity).

Saline soils will have excessive levels of soluble salts in the soil solution which are a combination of positively and negatively charged ions (for example, table salt; Na^+Cl^-). High levels of ions (positive and negative) from soluble salts restrict normal water uptake by plant roots, even when soils are visibly wet, resulting in drought-stressed plants (“osmotic effect”).

Saline soils having higher levels of calcium (Ca^{2+})-based salts will have good structure. That happens as calcium (Ca^{2+}) ions encourage aggregation of soil particles called flocculation (clumping together), resulting in well-defined pores facilitating free water movement through the soil profile.

In contrast to saline soils, sodic soils are highly saturated with sodium ions (Na^+) at the soil cation exchange sites. Sodic soils have extremely poor soil structure with dense soil layers, resulting in very slow permeability of water through the soil profile. The poor structure of sodic soils is due to three reasons:

- High sodium levels in combination with low salt levels can promote “soil dispersion,” which is the opposite of flocculation. Ions such as sodium (Na^+), and in some cases magnesium (Mg^{2+}), cause the breakdown of soil aggregates (soil dispersion), resulting in poor soil structure (low “tilth” qualities). Forces that hold clay particles together with soil aggregates are weakened greatly when excessive sodium (Na^+) ions are attached to the clay particles and when wet clay particles break away easily from soil aggregates.
- As excessive sodium (Na^+) levels increase, the tendency of soil aggregates is to disperse, and the released clay and silt particles then clog soil pores when washed down the soil profile.
- When highly saturated with sodium (Na^+) ions, the degree of swelling of expanding-type clays (smectite) increases. These soils are common in our region. As these soils swell (expand), the larger pores responsible for water drainage are constricted (Brady, C.B., and Weil, R.R. 2008. Pages 420 and 422, Chapter 10, “The Nature and Properties of Soils,” 14th edition, revised).

Due to poor soil structure, when wet, sodic soils will be gummy and may seem like they have “no bottom” to them, and when dry, they can be very hard.

OBJECTIVES:

Remediation of soil sodicity requires application of amendments that supply Ca^{2+} followed by salinity remediation practices of improving soil drainage and lowering the groundwater level. Ca^{2+} displaces Na^+ from the cation exchange sites and Na^+ moves into soil solution where it converts into a salt (Na_2SO_4) and leaches out with rainfall or irrigation.

An effective way to lower groundwater levels is to install a field tile drainage system. Since tiles are generally three to four feet below the surface, the efficiency of a tile drainage system depends upon the permeability of soil layers above the tiles. This requires analyzing soils for salts and Na^+ . In case of high Na^+ levels, not adding Ca^{2+} can render tiling ineffective. That could be achieved by sampling the areas in question and getting the samples analyzed by a soil laboratory. For detailed information on how to properly sample soils, please refer to the NDSU Publication: SF-1809; "Soil Testing Unproductive Areas". Another NDSU publication that provides detailed information regarding the suitability of soils for tiling is: SF-1617; "Evaluation of Soils for Suitability for Tile Drainage Performance". Challenges for landowners considering tiling could be:

- 1. What if high levels of sodium in the soils they would like to tile exist?**
- 2. If there are excess levels of sodium requiring application of soil amendments, what should be done first; apply the amendments or tile the land?**

In July 2014, the Langdon Research Extension Center (LREC) tilled a field that had excessive levels of Na^+ and moderately high levels of soluble salts. This consisted of 12 research plots with three replications. In order to replicate field conditions, the project site was tilled in July 2014 prior to starting sodicity remediation by applying soil amendments that are suitable and easily available to northeast North Dakota growers.

The following objectives were set in order to achieve research goals.

- Can tiling be successful on sodic or saline-sodic soils prior to starting sodicity remediation?
- Comparing the relationship between varying water table levels and resulting soil salt and sodium levels.
- Analyzing water samples from the lift station, upstream and downstream for human and livestock health.

TRIAL LOCATION AND SITE DESCRIPTION:

This trial site is located at the NDSU Langdon Research Extension Center, Langdon, North Dakota. As per web soil survey, soil series are Cavour-Cresbard and Hamerly-Cresbard loams.

TRIAL DESIGN AND PLOT SIZE:

Trial design is randomized complete block. Each plot is 325 X 80 feet.

METHODOLOGY:

Soil Chemical Analysis

Four feet deep soil samples in 12" increments from each plot were collected in September 2014 and June 2016. Overall, there were 48 soil samples per year (12 plots x 4 depths = 48 samples). All samples and depths were analyzed for Salts (Electrical Conductivity) and sodium (Sodium Adsorption Ratio) along with other chemical properties.

Weekly Groundwater Level Measurements

Groundwater levels were measured on a weekly basis from May-October through the observation wells in each plot in 2015 and 2016.

Water Sample Analysis

Water samples were collected from the Langdon REC Groundwater Management Research Project site (lift station), upstream and downstream in fall-2015 and May, July and September of 2016. The samples were analyzed by the ND Department of Health for Group 2 complete mineral chemistry, Group 7 trace metals and Group 30 nutrients.

Treatments and Replications

Soil amendment rates were calculated to bring the SAR (SAR-final) numbers to an acceptable level of 3 in the 1st foot. This was done by deducting three from the actual SAR numbers (SAR-initial). SAR-final values were converted into Exchangeable Sodium Percentage (ESP) by using the formula given in “Diagnosis and Improvement of Saline and Alkali Soils” (USDA Salinity Laboratory Staff, Agriculture Handbook No. 60, 1954. Page-26). Gypsum rates were then calculated by using standard formula given in the same handbook (page-49). For each ton of 100% pure gypsum, 0.19 ton of 100% pure elemental sulfur was applied (Reclaiming Saline, Sodic, and Saline-Sodic Soils. University of California, ANR Publication 8519, August 2015). Considering the very low solubility of Versalime, for each ton of 100% pure gypsum, three tons of VersaLime were applied. Differences in amendment purities were compensated by using the formula given in “Reclaiming Sodic and Saline/Sodic Soils” (Drought Tips Number 92-33, University of California Cooperative Extension, 1993).

The following treatments were applied in three replications.

- i. Control.
- ii. Full rate of 99.5% pure gypsum to lower soil SAR-final levels to 3.
- iii. Full rate of VersaLime to lower the soil SAR-final levels to 3.
- iv. Full rate of 90% pure elemental sulfur (S°) to lower the soil SAR-final levels to 3.

Details of amendment rates for each treatment and replication is in the table below.

Treatment number	99.5% Gypsum tons/plot	90% Elemental Sulfur tons/plot	VersaLime tons/plot
R1T1	0	0	0
R1T2	4.47	0	0
R1T3	0	0	8.74
R1T4	0	2.10	0
R2T1	0	0	0
R2T2	7.25	0	0
R2T3	0	0	30.45
R2T4	0	0.61	0
R3T1	0	0	0
R3T2	10.67	0	0
R3T3	0	0	22.93
R3T4	0	2.16	0
Total	22.40	4.87	62.14

Note: Gypsum and elemental sulfur were applied on June 29th, whereas, VersaLime was applied on July 23rd 2015. After spreading, all of the amendments were rototilled into the soil. Control plots were also rototilled for uniformity purposes. Control structures for all of the treatment were fully opened right after the incorporation of the amendments in order to simulate free drainage and achieve maximum leaching conditions.

RESULTS AND DISCUSSION:

Can Tiling Be Successful on Sodic or Saline-Sodic Soils Prior to Starting Sodicty Remediation

Soil salt and sodium levels were assessed at the time of tiling and two years after tiling. Tiling prior to starting sodicty remediation can actually elevate the soil sodium levels due to the leaching of soluble salts under improved drainage conditions.

Cumulative data showed a decrease in soil salt levels (EC) ranging from 42.17% to 71.85% for all treatments and depths. Unit decreases ranged from -3.57 to -6.52 dS/m.

Soil pH increased for all treatments and depths. The percent difference ranged from 7.17% to 18.64%, whereas, unit increases ranged from 0.53 to 1.28.

Soil sodium levels gave mixed results. Seven out of the 16 results showed a decrease in SAR levels ranging from 3.29% to 32.66% with unit decreases of -0.44 to -5.15. Nine remaining results showed an increase in SAR levels. The increase difference in percentage ranged between 6.90% and 28.46%. Unit increases ranged from 1.09 to 5.04.

Cumulative Data		Before Amendments (2014)			After Amendments (2016)			Differences					
Trt. #	Depth (in.)	EC (dS/m)	pH	SAR	EC (dS/m)	pH	SAR	EC Dif. (%)	EC Dif. (dS/m)	pH Dif. (%)	pH Dif. (units)	SAR Dif. (%)	SAR Dif. (units)
T1 (CT)	0-12"	9.07	6.91	13.97	2.55	7.78	11.03	-71.85	-6.52	12.49	0.86	-21.08	-2.95
	12-24"	7.32	6.97	11.19	3.17	7.72	8.85	-56.72	-4.15	10.71	0.75	-20.95	-2.34
	24-36"	7.00	7.31	11.66	2.52	7.91	9.94	-63.98	-4.48	8.26	0.60	-14.77	-1.72
	36-48"	6.21	7.05	13.52	2.15	8.10	13.07	-65.34	-4.06	14.95	1.05	-3.29	-0.44
T2 (GP)	0-12"	9.41	6.88	16.32	3.40	7.63	20.39	-63.92	-6.02	11.00	0.76	24.90	4.06
	12-24"	9.53	6.98	17.56	4.63	7.94	19.11	-51.38	-4.90	13.81	0.96	8.83	1.55
	24-36"	9.18	7.08	17.72	4.43	7.99	22.76	-51.71	-4.75	12.90	0.91	28.46	5.04
	36-48"	10.21	7.26	21.86	3.49	8.10	23.81	-65.83	-6.72	11.47	0.83	8.91	1.95
T3 (VL)	0-12"	9.20	6.89	15.77	3.47	7.83	10.62	-62.27	-5.73	13.59	0.94	-32.66	-5.15
	12-24"	10.03	7.14	13.72	4.71	7.83	14.88	-53.06	-5.32	9.72	0.69	8.41	1.15
	24-36"	9.17	7.35	15.85	4.46	7.88	16.94	-51.40	-4.71	7.17	0.53	6.90	1.09
	36-48"	8.39	7.19	20.01	3.51	8.05	18.84	-58.20	-4.88	11.91	0.86	-5.83	-1.17
T4 (ES)	0-12"	9.49	6.85	18.74	4.33	7.74	16.49	-54.32	-5.15	13.05	0.89	-11.99	-2.25
	12-24"	8.47	7.01	15.40	4.90	7.99	18.54	-42.17	-3.57	13.93	0.98	20.36	3.14
	24-36"	8.55	7.03	15.16	4.64	7.86	18.62	-45.79	-3.92	11.85	0.83	22.80	3.46
	36-48"	9.14	6.89	17.03	3.72	8.17	19.43	-59.34	-5.42	18.64	1.28	14.06	2.40

Note: CT stands for control, GP for gypsum, VL for VersaLime (beetlime) and ES for elemental sulfur.

Relationship Between Groundwater Levels and the Varying Salt and Sodium Levels

Though there are no conclusive results yet, however, two plots with the shallowest average groundwater levels in 2015 and 2016 (R3T2 and R3T4) showed the highest increase for sodium (SAR), whereas, salts levels (EC) decreased considerably.

Treatment	2015 Av. GW Level (feet)	2016 Av. GW Level (feet)	2015-2016 Av. GW Level (feet)	Difference (feet)
R1T1 (CT)	4.89	3.52	4.21	1.38
R1T2 (GP)	5.14	3.47	4.31	1.67
R1T3 (VL)	5.65	4.53	5.09	1.11
R1T4 (ES)	4.13	3.63	3.88	0.50
R2T1 (CT)	4.70	4.29	4.50	0.42
R2T2 (GP)	4.73	4.27	4.50	0.46
R2T3 (VL)	5.14	4.45	4.79	0.69
R2T4 (ES)	4.71	4.33	4.52	0.38
R3T1 (CT)	3.74	3.53	3.64	0.21
R3T2 (GP)	3.73	2.69	3.21	1.03
R3T3 (VL)	4.10	3.25	3.68	0.85
R3T4 (ES)	3.14	2.70	2.92	0.44

Water Quality Draining from the Research Project Site for Human and Livestock Health

All minerals and nutrients affecting human and livestock health, were found to be within the acceptable limits in the samples coming out the Langdon REC Groundwater Management Research Project site.

CONCLUSION:

Based on two year's cumulative data, it could be concluded that soil sodium levels did increase considerably in 56.25% samples. Increased sodium levels mean higher amendment costs and longer wait to achieve maximum productivity. Landowners considering tiling, should consider the following recommendations before installing an expensive tile system. That will save them money and ensure correct use of technology:

- Potential fields **“should be analyzed for salts and sodium”**.
- If sodicity is established, **“application of soil amendments should be considered before tiling”**.

