Saline and Sodic Soils: Soil Testing and Amendments

CHERYL L. REESE, PRESENTING TODAY

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REDFIELD SALINE / SODIC SOIL WORKSHOP
REDFIELD, SD
JULY 9TH, 2015
In the past, referred to as ‘Alkali Spots’

From ‘NC Region Research Pub. No. 221: Chemical Soil Test Procedures for NC Region’

Another type of salt-affected soil is termed a sodic or alkali soil. They have a low total soluble salt content, a high pH (usually 8.5 or higher) and exchangeable sodium in excess of 15 percent of the cation exchange capacity. These soils usually are dispersed due to the excessive sodium (2, 5). Salt-affected soils often have a compacted condition due to the presence of soluble salinity (20).

From Minnehaha 1958 Soil Survey Manual

Alkali soil. Generally, a highly alkaline soil. Specifically, an alkali soil has so high a degree of alkalinity (pH 8.5 or higher), or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that the growth of most crop plants is reduced.

Photo Credit: Stacy Turgeon, NRCS DC

Dispersed Soil

Erosion

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Pierre Shale

- Spink County
- Pierre shale close to surface in many areas.

- Many of the problem salts come from the Pierre Shale

Figure 4. Cross section showing stratigraphic relationships and structure of geologic units in eastern Spink County, South Dakota.
Soil Testing For Salts
Terms to Know: Soil Testing Review

- **EC (Electrical Conductivity):**
  - Measurement of total salts

- **CEC (Cation Exchange Capacity):**
  - Soils’ ability to hold positively charged cations

- **ESP (Exchangeable Sodium Percentage):**
  - Measurement of sodium on exchange sites in soil (*from CEC*)

- **SAR > 4 may be considered sodic! (previously > 13)**
- **ESP > 5 = Sodic (previously > 15)**

- **SAR (Sodium Adsorption Ratio):**
  - Measurement of the relative amount of sodium, when compared to total amount of salts (*from saturated extracts*)
  - **NOTE ABOUT SAR:** Not as commonly used as ESP
Cation Exchange Capacity (CEC)

- Total amount of cations that a soil can hold.
- The greater the soil CEC, the greater the ability the soil has to store plant nutrients.
- Soil CEC increases as:
  - Amount of clay increases
  - Amount of organic matter increases
  - Soil pH increases

http://www.tankonyvtar.hu/hu/tartalom/tamop425/0032_talajtan/ch05s04.html
CEC: Too much sodium on exchange sites = Sodic

- Sodic Soil = Dispersion
  - pH > 8.0

- No water movement
  - Erosion
  - Root limitation
CEC: Too much Calcium (Ca) + Magnesium (Mg) on exchange sites = Saline

- High pH, 7.8 – 8.0 range
- Drought like conditions
- Poor germination and growth

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Soil Sampling for Salts:
1. Where are salts located in the soil profile?
2. Sampling procedures?

TOM DESUTTER AND CHERYL REESE
Soils at our field trip today.

- *Cresbard-Cavour-Heil complex, 0 to 3 percent slopes*
First, what are soils characteristics?
http://casoilresource.lawr.ucdavis.edu/gmap/
Soils at our field trip today.
Soil Horizon Names: Bn, Btnzy, Bk etc.

- Soils are described with Upper case and Lower case letters assigned to the different horizon.
- Master horizons A, E, B, C primarily in our area.
- Lower case letters added to describe the characteristics of the horizons.
- Bk = Carbonates or lime present.
- Bn - Accumulation of sodium on the exchange complex sufficient to yield a morphological appearance of a natric horizon.
- Bt - Accumulation of silicate clay that either has formed in the horizon and is subsequently translocated or has been moved into it by illuviation.
- By - Accumulation of gypsum.
- Bz - Accumulation of salts more soluble than gypsum.
Soil Horizon Names
Lower case ‘n’ = sodium horizon

Cresbard-Cavour-Heil complex, 0 to 3 percent slopes (SSURGO Export: 2014-09-18)
Ferney vs Cresbard Soil Series

• Taxonomy can help tease out the differences
• Ferney: Fine, smectitic, frigid Leptic Natrudolls
• Cresbard: Fine, smectitic, frigid Glossic Natrudolls
• So, what is the deal between “Leptic” and “Glossic”?
Leptic

- The zone of Na is close to the soil surface
- Textbook columnar structure

Photo by M. Ulmer

Photo by R. Utter (NDSU)
Ferney = Leptic
Btn horizon or natric horizon closer to surface
Glossic

• The zone of Na is deeper in the profile
• The columns have been “degraded”
Cresbard = Glossic
Btn horizon or natric horizon 14 inch deep
Soil Sampling: Why is locating natric (sodium) horizon important?

• What happens when sodium is high?
• Doug Malo’s presentation?
• Flocculation or dispersed. Looks like pavement, no soil structure.

• For agronomic soil nutrient testing: 0-6 inch and 6-24 for mobile nutrients
  • Total of 2 feet

• For tile drainage evaluation in areas with potential natric horizons:
  • At least 3 feet, or if possible to the depth of the tile installation

Sounds like a lot of work, why so deep?
So, how deep again?

- If you are evaluating soils for tile drainage then you need to look down to at least the 3 foot depth.
- A 0-6” sample does not allow for adequate evaluation.

SAR value higher deeper in the soil profile, Leptic Natric horizons,

He et al, 2014 unpublished data
Saline and Sodic Soils are different and must be managed differently.

- If Ca and Mg moved out of soil profile near tile, and sodium is high.
- May negatively impact the flow of water into the tile line.
- Observation: Water does not flow from the tile yet the field remains wet.

*Slide from Tom DeSutter, NDSU*
Management Options:
Management Steps

• 1. Soil test the area
• 2. Test for EC (total salts)
• 3. If soil is dispersed, test for Sodium
  • Soil test result will most likely be ESP (Exchangeable Sodium Percent)
• 4. Know the soil test methods so you can correctly interpret the results.
  • If you have questions, contact one of us!!
• 5. Now what to do?
• 6. Different options based on type of salts
Managing Salty Soils

• **Saline Soil Options (Ca + Mg Salts):**
  • Tile to move calcium and magnesium salts from surface
    • Will take time and need rainfall
  • Perennial vegetation to lower the water table
    • Remember high water table is bringing salts to the surface.
  • Plant salt tolerant crops

• **Sodic Soil Options (Na salts):**
  • Perennial vegetation to lower the water table
    • Remember high water table is bringing salts to the surface.
  • Soil Amendments??
Field experiments
Surface Chemical Amendments

- Split plot, randomized block
  - 4 blocks
- Treatments:
- 4 soil amendments
- 2 cover crop treatments:
  - Drilled into corn, V6
  - + or - cover crops
    - Barley and sugarbeets
About Elemental S

- **About these amendments and how they work:**
- Sulfur (S) lowers soil pH, releases calcium (Ca) from lime to exchange with sodium (Na) on exchange sites.
- Elemental S takes longer to react than gypsum.
- Because S must be oxidized to sulfate by soil bacteria.
- During the oxidation of elemental sulfur:
  - \(2 \text{ S} + 3 \text{ O}_2 \rightarrow 2 \text{ SO}_3\) (microbiological oxidation)
  - \(\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4\)
  - \(\text{H}_2\text{SO}_4 + \text{CaCO}_3 \rightarrow \text{CaSO}_4 + \text{H}_2\text{O} + \text{CO}_2\)

\[
\text{Na}^\text{clay} \text{ micelle} + \text{CaSO}_4 \leftrightarrow \text{Ca}^\text{clay} \text{ micelle} + \text{Na}_2\text{SO}_4 \text{ (leachable)}
\]

Need to have calcium in the soil for elemental sulfur.

Usually not a problem in SD.
About Gypsum (CaSO₄ * 2H₂O)

• **Myth about Gypsum:**
  - The short answer is that pure gypsum will not affect the pH of the topsoil when surface applied or incorporated by typical methods.

• **Gypsum and sodium, Facts:**
  - Research has shown that large amounts of gypsum (1-10 tons/acre) applied to sodic soils followed by large amounts of irrigation water may alleviate the sodium problem.
  - Excess Ca from the gypsum displaces the Na in the soil and the excess water leaches the displaced Na below the root zone of the planned crop.
  - This permits a crop to be grown successfully on that land.
  - Of course, the excess Ca will also displace other nutrient cations such as K and Mg, so the fertility program would need to be adjusted to compensate for this loss of nutrients.
About Gypsum (CaSO₄ * 2H₂O)

• Reaction of gypsum with sodium in soils:

\[
\text{Na}_2\text{CO}_3 + \text{CaSO}_4 \rightleftharpoons \text{CaSO}_3 + \text{Na}_2\text{SO}_4 \text{ (leachable)}
\]

\[
\text{Na}_{\text{clay micelle}} + \text{CaSO}_4 \rightleftharpoons \text{clay micelle} + \text{Na}_2\text{SO}_4 \text{ (leachable)}
\]
Pierpont: Soil Amendment / CC

Treatment:
- No salt amendment
- No Cover Crop
- Salts on soil surface

Treatment:
- Calcium Chloride
- Some Cover Crop
- Salts on soil surface

Treatment:
- Gypsum
- More Cover Crop
- Fewer salts on soil surface

Treatment:
- Elemental S
- Most Cover Crop
- Least salts on soil surface
Pierpont: Soil Amendment / CC

- Elemental Sulfur: Barley germinated.
- Gypsum: Some barley germinated.
- CaCl2: None
- No Salt: None

<table>
<thead>
<tr>
<th>Salt Treatment</th>
<th>lb/ac</th>
<th>tons /A</th>
<th>Cost / lb for amendment</th>
<th>Cost /A</th>
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<tbody>
<tr>
<td>Gypsum</td>
<td>7740</td>
<td>3.9</td>
<td>$0.12</td>
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<td>CaCl2</td>
<td>6607</td>
<td>3.3</td>
<td>$0.37</td>
<td>$2,444.53</td>
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<td>Elem S</td>
<td>1441</td>
<td>0.7</td>
<td>$0.37</td>
<td>$533.25</td>
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<tr>
<td>No Salt</td>
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<td>0.0</td>
<td>$0.00</td>
<td>$0.00</td>
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Based on SAR of 19
Soil Chemistry Summary at Sites Top 0-3 inches: Composite block samples

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<tbody>
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<td>Redfield</td>
<td>No Salt</td>
<td>NA</td>
<td>NA</td>
<td>5</td>
<td>4</td>
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<td>Redfield</td>
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<td>NA</td>
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<td>NA</td>
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<td>Old Pierpont</td>
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<td>Fall 2013</td>
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<td>NA</td>
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<td>Spring 2014</td>
<td>NA</td>
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<td>Sulfur</td>
<td>Spring 2014</td>
<td>NA</td>
<td>20</td>
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<tr>
<td>White Lake</td>
<td>No Salt</td>
<td>NA</td>
<td>NA</td>
<td>16</td>
<td>19</td>
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<tr>
<td>White Lake</td>
<td>Gypsum</td>
<td>Fall 2012</td>
<td>NA</td>
<td>16</td>
<td>18</td>
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<tr>
<td>White Lake</td>
<td>Sulfur</td>
<td>Fall 2012</td>
<td>NA</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>
Management Decisions?

• Is ESP = 4 or 5 the value where we apply amendments?

• Or where, careful management is started.
  • No more short season crops: soybeans or wheat???
  • Wheat followed by cover crop ok?

• More aggressive management?
  • Move to perennial crops?
  • Salinity tolerant alfalfa? Salt tolerant grasses?
Management Decisions: Water budgets are important to understand!

• What do you need to know?
• Soil water holding capacity.
• Rainfall during growing season.
• Evapotranspiration of the crop → How much water does the crop use in one year??
• Dwayne Beck has held workshops on this!!!
Amendment Impacts: Germination and Yield
## Redfield, 2015 Soybean Germination

<table>
<thead>
<tr>
<th>Soil EC (Sat. Paste)</th>
<th>2.5</th>
<th>2.9</th>
<th>6.2</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
<td>Drainage Type</td>
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<tr>
<td>Salt Treatment</td>
<td>No Drainage</td>
<td>Full Drainage</td>
<td>Control Drainage</td>
</tr>
<tr>
<td>Control</td>
<td>190212 B</td>
<td>189486 B</td>
<td>192390 AB</td>
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<td>Elemental Sulfur</td>
<td>223608 A</td>
<td>239580 A</td>
<td>214170 A</td>
</tr>
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<td>Gypsum</td>
<td>176418 B</td>
<td>231594 A</td>
<td>219978 A</td>
</tr>
<tr>
<td>CaCl2</td>
<td>190212 B</td>
<td>230142 A</td>
<td>180048 B</td>
</tr>
<tr>
<td>P Value</td>
<td>0.005</td>
<td>0.028</td>
<td>0.063</td>
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</tbody>
</table>
Pierpont 2015 Corn Germination

- Baseline soil test:
- SAR = 19
- EC = 20

<table>
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<tr>
<th>Treatments</th>
<th>Corn Population (Plants/A)</th>
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<tbody>
<tr>
<td>Control</td>
<td>7899 A</td>
</tr>
<tr>
<td>Elemental Sulfur</td>
<td>16262 A</td>
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<td>Gypsum</td>
<td>11151 A</td>
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<td>CaCl2</td>
<td>9293 A</td>
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<tr>
<td>P Value</td>
<td>0.40</td>
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</table>

<table>
<thead>
<tr>
<th>Saturated Paste Extract</th>
<th>EC</th>
<th>Ca (ppm)</th>
<th>Mg (ppm)</th>
<th>K (ppm)</th>
<th>Na (ppm)</th>
<th>SAR (Na/Sqrt)</th>
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<tbody>
<tr>
<td></td>
<td>20.46</td>
<td>389.35</td>
<td>2185.32</td>
<td>100.92</td>
<td>above range</td>
<td>23</td>
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<td></td>
<td>18.15</td>
<td>410</td>
<td>2573</td>
<td>77</td>
<td>4508</td>
<td>19</td>
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<td></td>
<td>21.15</td>
<td>426</td>
<td>3566</td>
<td>88</td>
<td>4541</td>
<td>16</td>
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<td></td>
<td>20.40</td>
<td>475</td>
<td>2269</td>
<td>68</td>
<td>4230</td>
<td>19</td>
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<td></td>
<td>20.04</td>
<td>425.14</td>
<td>2648.11</td>
<td>83.64</td>
<td>4426.27</td>
<td>19.42</td>
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Amendment and CC Impact on Yield: One year after amendment application.

<table>
<thead>
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<th>Soil Amendment</th>
<th>Grain Sorghum, bu/A</th>
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<tr>
<td>Control</td>
<td>123</td>
<td>0.26</td>
</tr>
<tr>
<td>CaCl2</td>
<td>97</td>
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<tr>
<td>Gypsum</td>
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<td></td>
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<tr>
<td>Elemental S</td>
<td>135</td>
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<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>Soil Amend.</th>
<th>Corn Yield, bu/A</th>
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<td>No CC</td>
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<td>154 b</td>
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<tr>
<td></td>
<td>CaCl2</td>
<td>168 b</td>
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<td>Gypsum</td>
<td>162 b</td>
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<td></td>
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<td>165 b</td>
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<tr>
<td>CC</td>
<td>Control</td>
<td>212 a</td>
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<tr>
<td></td>
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<tr>
<td></td>
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P value 0.07

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- NRCS-USDA: Conservation Innovation Grant (CIG Grant)
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- SD Soybean Research and Promotion Council
- South Dakota State University

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