**Improving Soil Health and Productivity of Sodic Soils**

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**Situation Statement:**

Approximately 10 percent (4.7 million acres) of agricultural land in North Dakota is considered to be sodic (J. Brennan, personal communication, NRCS North Dakota, 2008). Sodicity is caused by an excess amount of sodium on the soil exchange sites, in the soil solution, or both, and creates unfavorable chemical and physical soil conditions. As sodic soils are wetted and sodium ions become hydrated, swelling causes a reduction in pore size making transfer and movement of water and air through the soil function slower. Dispersion can also occur forcing clay particles away from one another resulting in clogged soil pores that forms a restrictive barrier or seal. Many of the negative impacts include, low water infiltration, poor aeration, low organic matter, high bulk density, surface crusting, runoff, erosion, and ultimately poor productivity.

A typical sodic soil has a “Natric” horizon, meaning accumulation of clay and Na, which can be located at various depths within a soil profile. These soils are also variable across the landscape making them difficult to manage. Recent NDSU research has found that swelling and/or dispersion can occur when the %Na is greater than 5 when the EC1:1 is less than 1.0 mmhos/cm. There are three main requirements for the management of sodic soils: (1) addition of calcium (Ca) or other flocculating cations, (2) downward moving high quality water, and (3) proper subsoil drainage. Calcium or potentially magnesium is needed to replace sodium on the soil exchange sites. Water is needed to dissolve the calcium source and to leach the sodium, and lastly drainage is needed to remove the sodium from the profile. In addition, maintaining an EC1:1 greater than 1.0 mmhos/cm is critical in reducing the potential for swelling and/or dispersion.

Another important step in sodic soil remediation is appropriate crop selection. Selecting a perennial crop such as alfalfa can provide benefits like increased macropores in both “shrink-swell” and compacted soils to allow for downward water flow and improved infiltration. The vigorous deep tap root of alfalfa will help penetrate the clay-rich Natric horizon, providing a path for water and amendments to move downward making remediation more efficient. Alfalfa is also a perennial high water use crop that will lower the water table and reduce evaporation at the soil surface. This will prevent the upward movement and deposition of salts in the rooting zone caused by high water tables. For the improvement of sodic soils, with the long-term goal of improving the soils’ potential to support soybean production, the application of amendments may be necessary. However, one must also understand the impacts that these amendments, and their rates of application, may have on soil health and plant yield and quality.

**Objectives:**

In this field study, the objectives were to:

1. Determine how flue-gas desulfurization gypsum (FGDG), sugar beet processing lime (spent lime), and potassium-magnesium sulfate (K-Mg) impact sodic soils at different rates of application under subsurface and surface drained systems, and
2. Determine how these treatments impact alfalfa yield and quality, and
3. Quantify the risks of swelling and/or dispersion and the IDC risk and severity for soybean.

These objectives are important to soybean producers because sodic soils often have low productivities, can often times be seen in patches within a field, and can be difficult to maneuver around with farm machinery and equipment. Therefore, a better understanding of (1) the effectiveness of amendments applied, (2) the removal or reduction of Na and root-zone salts by tile drainage and surface-only drainage, and (3) the ability for alfalfa to be grown as a cash crop in harsh soil conditions, all for the improvement of soil health and productivity of sodic soils, and the future production of soybean is needed. This research also provided valuable information for Extension programs to help educate farmers about management options for saline and sodic soils.

**Description of Research Conducted:**

Field plots were established at two sites near Delamere, North Dakota in the spring of 2014. Subsurface drainage was installed at one site in the fall of 2013 and the other site is surface drained only. Both sites share the same soil map unit, an Aberdeen-Ryan silty clay loam, sandy substratum. When the soils were field characterized, the tiled site resembled the Aberdeen series and the non-tiled site resembled the Ryan series. Both of the soils have a “Natric” horizon but are located at different depths in the profile. The depth to the Na at the tiled site is deeper in the soil profile and is generally found in the 6-12” depth. The Na in the non-tiled site is high throughout the profile. The EC at the tiled site is very low at the surface but drastically increases with depth. The non-tiled site is high at the surface. The low EC at the tiled site could cause some dispersion issues if amendments are not applied to increase flocculation.

A random complete block design (RCBD) was used at each site. The sites were divided into four replications that consisted of 10, 20 x 20 ft plots. Each replication contained a control and nine treatments that included three amendments at three different rates. FGDG and spent lime were applied at 5, 15, and 30 tons/acre and K-Mg was applied at 1, 2.5, and 5 tons/acre. All amendments were incorporated to the 4” depth using a rotary tiller. Alfalfa was harvested using a forage chopper five times in 2016 and three times in 2017. Harvestings occurred at approximately pre- to early-bloom stage. Soil cores were taken in the fall of 2016 and 2017 from each plot to a depth of four feet. Cores were dissected into 0-6, 6-12, 12-24, 24-36, and 36-48” samples, air dried, ground, and analyzed for %Na, EC, pH, N, P, K, and %CaCO3. For brevity, only the 2016 EC %Na, and %CaCO3 results from the 0-6” depth will be discussed. 2017 soil cores are still being processed.

**Findings:**

*EC1:1, %Na, and %CaCO3*

Overall, after three years of alfalfa, the EC1:1 values of the control (0-6”) at the non-tiled site (2.2 mmhos/cm) were higher than the tiled site (0.8 mmhos/cm) (Table 1). Because of the lower EC1:1 at the tiled site, a greater increase was observed in EC1:1 after application of amendments. For example, the highest rate of FGDG had a significantly greater EC than the control (1.8 vs 0.8 mmhos/cm respectively). In the non-tiled site the amendments only slightly impacted EC1:1 with no treatment being significantly different than the control.

The %Na values of the control plots at the tiled and non-tiled sites in fall 2016 were 7.9 and 6.2, respectively. (Table 1). After three years the only treatment different than the control at the tiled site was the highest rate of gypsum, and at the non-tiled site no treatments had significantly lower %Na compared to the control.

The influence of the spent lime was evident on soil %CaCO3 where, at the tiled site, the highest rate of application had the greatest value (2.4; Table 1) and was significantly different than the control. No significant differences were observed at the non-tiled site. Across all treatments at both sites the %CaCO3 was less than 2.5, a cutoff level for IDC risk and severity.

The four treatments at the tiled site that reduced the potential for swelling and/or dispersion (EC1:1 less than 1.0 when %Na is greater than 5.0) were the two highest rates of gypsum and the highest rates of spent lime and K-Mg (Table 1). As stated above, the reduced potential of swelling and/or dispersion occurs when %Na is reduced to near 5 and the EC1:1 is greater than 1.0. If application rates of gypsum are high enough an increase in EC will occur, and %Na will decrease. Although spent lime is fairly insoluble the highest rate did contribute enough calcium to reduce %Na. The highest application rate of highly soluble K-Mg increased EC1:1 enough to reduce the potential of swelling and/or dispersion to ‘moderate.’ At the non-tiled site, due to values of EC1:1 being twice as high as 1.0 mmhos/cm, and %Na values below 8, there is little risk for swelling and/or dispersion of this surface soil.

The risk for IDC of soybean for the tiled site was increased to ‘very high’ due to the increase in EC1:1 on plots with the two highest rates of gypsum and for the plots receiving the highest rate of K-Mg. However, with increased downward movement of water these EC levels should decrease. Due to naturally high values of EC1:1 at the non-tiled site all plots had IDC ratings of ‘very high.’

Although a hypothesis of this study was that the planting of a perennial crop (alfalfa) and the installation of tile drainage would assist the downward translocation of the amendments, there was no evidence that the 6-12” depth had been influenced, positively or negatively, by amendments. Thus, positioning amendments at the depth where the Natric horizon is located is key for timely management of sodic soils.

*Alfalfa Yield and Quality*

There were no significant differences in alfalfa yields at the tiled site in either 2016 or 2017, or in the non-tiled site in 2017, with averages of 6.2, 3.7, and 4.3 tons/acre, respectively(Table 2). The only significant differences in 2016 at the non-tiled site were between the lowest and highest rates of K-Mg. The overall 2016 non-tiled site average yield was 8.4 tons/acre. The alfalfa at the non-tiled site was consistently the greatest which was not expected based on the first two years of the study where yields were less in 2014 and 2015 compared to the tiled site. The water table is normally closer to the soil surface at the non-tiled site which may have allowed for more plant-available water during these past two fairly dry summers, even though the overall site EC1:1 is greater.

Alfalfa quality was not hindered or improved in either 2016 or 2017 compared to plants from the control plots (Table 3). This indicates that the application rates of the amendments used in this study are not detrimental to forage quality, although they don’t improve quality either.

**Summary:**

Many factors must be considered when the objective is to improve the productivity of sodic soils. First and foremost, there must be an understanding of the %Na and EC within the soil profile so that the amount of calcium needed can be calculated to replace the sodium in the soil, and a cost-effective amendment must be used. The target values to reduce the likelihood of soil swelling and/or dispersion are a %Na less than 5 when the EC1:1 is less than 1.0 mmhos/cm. The amendments and their rates of application used in this study did not generally impact yields and forage quality at either site. Although the application of amendments is needed to improve the productivity of sodic soils over the long-term, the type of amendment and its rate of application may increase the IDC severity risk for soybean in the short term.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Water Management | Treatment | Rate of Application | EC1:1 | %Na | %CaCO3 | S/D Potential† | IDC Risk and Severity‡ |
|  |  | tons/acre | mmhos/cm |  |  |  |  |
| Tiled | Control | 0 | 0.8 B | 7.9 A | 1.1 BC | High | Moderate |
|  | FGD Gypsum | 5 | 0.8 B | 7.6 AB | 0.8 C | High | Moderate |
|  |  | 15 | 1.4 AB | 7.0 AB | 1.4 ABC | Medium | Very high |
|  |  | 30 | 1.8 A | 5.3 B | 0.9 BC | Medium | Very high |
|  | Spent Lime | 5 | 0.4 B | 7.9 A | 1.5 ABC | High | Moderate |
|  |  | 15 | 0.7 B | 6.4 AB | 2.2 AB | High | Moderate |
|  |  | 30 | 0.8 B | 5.8 AB | 2.4 A | Medium | Moderate |
|  | Potassium-Magnesium Sulfate | 1 | 0.7 B | 8.2 A | 1.0 BC | High | Moderate |
|  |  | 2.5 | 0.7 B | 7.8 A | 0.7 C | High | Moderate |
|  |  | 5 | 1.3 AB | 7.4 AB | 1.7 ABC | Medium | Very high |
| Non-tiled | Control | 0 | 2.2 AB | 6.2 AB | 0.7 A | Low | Very high |
|  | FGD Gypsum | 5 | 2.1 AB | 5.8 AB | 1.6 A | Low | Very high |
|  |  | 15 | 2.1 AB | 6.4 AB | 1.0 A | Low | Very high |
|  |  | 30 | 2.7 AB | 4.5 B | 0.9 A | Low | Very high |
|  | Spent Lime | 5 | 2.0 AB | 6.3 AB | 1.3 A | Low | Very high |
|  |  | 15 | 2.0 AB | 5.8 AB | 1.4 A | Low | Very high |
|  |  | 30 | 2.0 AB | 5.3 AB | 2.3 A | Low | Very high |
|  | Potassium-Magnesium Sulfate | 1 | 1.7 B | 7.0 A | 1.5 A | Low | Very high |
|  |  | 2.5 | 2.3 AB | 6.3 AB | 1.3 A | Low | Very high |
|  |  | 5 | 3.0 A | 6.2 AB | 1.0 A | Low | Very high |

† S/D Potential; Potential for the soil to either swell and/or disperse, based on the criteria that swelling and dispersion will likely occur if the EC1:1 is less than 1 mmhos/cm when the %Na is greater than 5.

‡ IDC Risk and Severity; based on <https://www.agvise.com/educational-articles/managing-soybean-idc-soil-testing-carbonates-and-salts/>

Table 1. 2016 soil variables used to determine the effectiveness of treatments for reducing the potential for swelling and dispersion and how the treatments influence IDC risk and severity for soybean. Numbers within the same soil variable within the same water management followed by the same letter are not significantly different at alpha of 0.05.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | -------------Yield------------ | |
| Water Management | Treatment | Rate of Application | 2016 | 2017 |
|  |  | ------------------------------tons/acre-------------------------- | | |
| Tiled | Control | 0 | 6.2 A | 4.0 A |
|  | FGD Gypsum | 5 | 6.3 A | 3.7 A |
|  |  | 15 | 6.2 A | 3.2 A |
|  |  | 30 | 5.9 A | 3.6 A |
|  | Spent Lime | 5 | 5.2 A | 3.4 A |
|  |  | 15 | 6.3 A | 4.3 A |
|  |  | 30 | 5.9 A | 3.6 A |
|  | Potassium-Magnesium Sulfate | 1 | 6.3 A | 3.6 A |
|  |  | 2.5 | 7.1 A | 4.1 A |
|  |  | 5 | 6.4 A | 3.8 A |
| Non-tiled | Control | 0 | 8.9 AB | 4.1 A |
|  | FGD Gypsum | 5 | 8.4 AB | 3.7 A |
|  |  | 15 | 8.3 AB | 4.8 A |
|  |  | 30 | 8.4 AB | 4.1 A |
|  | Spent Lime | 5 | 8.2 AB | 3.9 A |
|  |  | 15 | 8.3 AB | 4.0 A |
|  |  | 30 | 8.1 AB | 4.8 A |
|  | Potassium-Magnesium Sulfate | 1 | 9.4 A | 4.6 A |
|  |  | 2.5 | 8.5 AB | 4.6 A |
|  |  | 5 | 7.4 B | 4.1 A |

Table 2. 2016 and 2017 alfalfa yields. Numbers within the same year within the same water management followed by the same letter are not significantly different at alpha of 0.05.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Quality Parameter | -------2016------ | | -------2017------- | |
|  | Tiled | Non-tiled | Tiled | Non-tiled |
| %Ash | 10.3 | 1.5 | 9.5 | 10.5 |
| %Crude Protein | 26.0 | 23.5 | 25.4 | 21.3 |
| %Neutral Digestible Fiber | 29.8 | 32.6 | 31.9 | 30.9 |
| %Acid Digestible Fiber | 20.8 | 22.4 | 22.7 | 22.4 |
| %Calcium | 1.17 | 1.04 | 1.20 | 1.35 |
| %Phosphorus | 0.43 | 0.38 | 0.39 | 0.32 |
| %Nitrogen | 4.2 | 3.8 | 4.1 | 3.4 |

Table 3. 2016 and 2017 alfalfa quality parameters. Average values across each quality parameter are reported since no significant differences were determined within each year within water management (tiled and non-tiled).