Soil Amending with Tiger 90CR

Correcting Soil Conditions

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Introduction

With the increased need for world food production, in the new millennium, and the reduction in good farm land around the world, we must look at maximizing yields and quality of our crop production. To do this, however, means that land that is not suitable to crop production must be put into production. This means that we must look at the improvement of these soils. Improvements in soil texture, structure, and growth characteristics are all possible by using chemical methods of soil amending on alkali and saline-alkali soils.

What is meant by soil amending? Simply put it is the process of adding a material to the soil to change and improve the characteristics of that soil and aid in plant growth. In the context that soil amending is being discussed in this paper, we will concentrate on changing the physical characteristics of calcareous, alkali and saline-alkali soil, such as can be found across North America.

The following discussion will concentrate on the use of chemical methods of soil amending. That is the addition of some materials like Tiger 90CR degradable sulphur and Gypsum. These products are not necessarily considered chemicals, but in the context used in this discussion, they are not considered cultural practices and are therefore considered chemical methods.

Discussion:

Alkali Soils:

Alkali soils (or Sodic soils), are generally sodium-saturated in a dispersed or deflocculated condition. In this condition water cannot enter or is impaired from entering the soil. They are also characterized by pH values above 7.0, although generally speaking pH levels between 6.7 and 7.3 are considered neutral. Soils where the pH is above 8.4 are said to be alkali because of excess sodium. These soils will exhibit less than ideal growth and in some instances salt toxicity will be present in crops grown under these conditions.

In almost all instances of alkaline soils with a pH between 7.0 and 8.4, we will find excess lime (Calcium Carbonate). Excess lime values of 1.0 or more will reduce the availability of phosphorous and other positively charged anions, it can also cause the soil to crust (in instances where high sodium levels are also present). Many western soils contain between 4 and 8% excess lime, some contain 15 to 20% (Stukenholtz lab manual).

High sodium soils will tend to exhibit compaction, which reduces the degree of aeration by decreasing the pore sizes in the root zone. This in turn will restrict root growth and reduce absorption of phosphorus and other nutrients. This soil would be said to be in a deflocculated condition.

Alkali soils will exhibit the following characteristics:

The dispersed sodium soil becomes puddled, impervious to water and air, sticky, and greasy when wet and hard when dry.

1) Contain an excess of sodium (greater than 10% of the total exchangeable cations)

2) Soil tilth and physical properties are poor as a result of the excess sodium.

3) The pH is nearly always above 8.5, in sever alkaline conditions.

4) The conductivity is nearly always less then 1.5 – 3 mmhos/cm.

5) Development of alkali soils:

   a. An excessive quantity of sodium in the irrigation water will result in greater than 10 % exchangeable sodium.
   b. An alkali soil commonly forms as a result of improving saline-alkali soils. Upon lowering the water table and subsequent leaching, soluble salts are removed in the drainage water. Since sodium is attached to the exchange complex, it remains to disperse the soil. The dispersed sodium soil becomes puddled, impervious to water and air, sticky, and greasy when wet and hard when dry. The pH sodium disperses the organic matter resulting in a black or dark brown color. These strongly alkaline soils may even dissolve plant roots.

6) Reclamation of alkali soils:
   a. Establish drainage (at least three feet)
   b. Add chemical amendments and leach with quality water.
      i) in calcareous soils, can use elemental sulfur
      ii) in non-calcareous soils, one could use gypsum
      iii) the purpose of adding sulfur is to acidify the soil which dissolves calcium, which in turn replaces sodium from the exchange complex. The addition of water leaches the replaced sodium sulfate from the soils. This accomplishes the same process as gypsum in non-calcareous soils.

Sulfur use on Naturally Alkaline or Over limed Soils:

Iron deficient Peanuts on Alkaline soil in Texas, USA.

Frequently, symptoms of nutrient deficiencies are seen in crops growing on soils which are neutral or alkaline and on soils which have been limed excessively. Because of the high pH values, the availability of certain essential nutrients to crops has been reduced considerably. These nutrient deficiencies may be corrected temporarily by foliar applications, which is a procedure used in general farming practices. However, in intensive crop production on relatively small acreage's, reduction of the soil pH may be more practical and permanent. This is especially true if the pH is not significantly higher than desired. Any of the acid-forming compounds may be used for this purpose, but the application of elemental sulphur is the practice usually followed to reduce pH.

The following chart gives the amount of elemental sulfur needed to reduce the soil pH to about pH 6.5 for a depth of 7 inches on a carbonate-free soil.

	Broadcast application lbs S/acre		Band/Furrow Application lbs. S/acre	
Source: Midwest Laboratories "Agronomy Handbook", page 40.				
Soil pH	**Sandy Soils**	**Clay Soils**	**Sandy Soils**	**Clay Soils**
7.5	400-600	800-1000	200-250	300-500
8.0	1000-1500	1500-2000	300-500	600-800
8.5	1500-2000	2000 +	500-800	800 +
9.0	2000-3000		800 +	

In many calcareous or alkaline soils it is not economically feasible to use the amount of acidifying material required on a broadcast basis to neutralize the total alkalinity of the soil mass. ***Soil zones favorable for root growth and nutrient uptake can be created by applying acidifying Tiger 90CR sulphur in bands or furrows.***

Saline-alkali Soils:

In order to improve sodium affected soil, one must add an amendment which will cause the exchange and removal of the sodium. There are a number of products which can be used in the reclamation process. The cations calcium and iron are the two most common. Gypsum (CaSo4) has traditionally been the most common product in reclaiming alkali soils. Although in many situations gypsum is relatively insoluble it can release soluble calcium which replaces exchangeable sodium. Lime (CaCo3) is not a good reclamation agent because it is very insoluble above a pH of 7. If the soil pH is below 6.0, agricultural lime can be used. ***If an excess of free lime (CaCO3) is present, Tiger 90CR sulphur can be used as an amendment because the sulphur is converted to sulphuric acid through the microbial oxidation by Thiobacillus Thioxidans bacteria. The sulphuric acid then reacts with lime (CaCO3) in the soil and forms gypsum (CaSO4).*** Elemental sulfur is slightly slower than gypsum because it needs to oxidize to sulphuric acid. ***Tiger 90CR sulphur, because of its improved breakdown and quicker sulphate conversion (thus quicker sulphuric acid conversion) makes an effective soil amendment, in soil with free lime present above 1.0%. The efficiency ratio also minimizes trucking and application costs.*** The following chart* shows the type of soil amendment used and the amount to drop the pH in equivalent amounts.

Amendment Material	Equivalent Amounts
Tiger 90CR	1000
Gypsum	5400
Sulfuric Acids (98%)	3060
Calcium Chloride	4600
Ferric Sulfate	4160
Ammonium Sulfate	4120
Ammonium Polysulfide	2220
Ammonium Thiosulfate	3850
Sulfur Dioxide (50%)	2000

*** Source: Stukenholtz Laboratory Manual.**

Saline-alkali soils will generally exhibit the following characteristics:

1) Contain an excess of salts and sodium
2) The soils contain conductivity values greater than 1.5 – 3 mmhos/cm.
3) There is more than 10% exchangeable sodium
4) The pH is usually less then 8.5. The acidic and neutral salts offset the very alkaline sodium salts preventing the pH from being excessively high.
5) The physical properties are usually good. Even when sodium is present an excess of salts keep the soil in good physical condition.
6) Development of saline-alkali soils:
    a. High water tables.
    b. Irrigation water high in both sodium and salts.
7) Reclamation of saline-alkali soils (corrective treatment).
    a. Establish drainage (at least three feet).
    b. Add Tiger 90CR Sulphur to calcareous soils and gypsum to non-calcareous soils.
    c. Allow sufficient time for gypsum to dissolve and sulfur to be oxidized to sulfuric acid. Then leach out sodium with water. (see below for recommended rate of water for leaching)

Sulfur for Reclamation of Alkali and Saline-Alkali Soils:

Alkali or Sodic soils, including saline-alkali soils, are sodium-saturated in a dispersed or deflocculated condition. In this condition the water cannot or is impaired from entering the soil. In contrast, the calcium-saturated soil is flocculated, which permits good water penetration and movement.

Therefore, to bring about the reclamation of Alkali or Sodic soils, the excess sodium on the cation exchange complex must be replaced by calcium, which may be supplied by applying gypsum or some other soluble calcium salt directly to the soil. For reclamation of soils to be successful, the displaced sodium must be removed from the root zone by leaching with water of suitable quality, which can be determined by analysis.

Gypsum or Sulphur Needed to Replace Exchangeable Sodium*			
Sodium to be Replaced		Amount to Supply	
Meq/100 g	PPM	Gypsum/acre ft. (in tons)	Sulphur/acre ft. (in tons)
1	230	1.7	0.32
2	460	3.4	0.64
3	690	5.1	0.96
4	920	6.8	1.28
5	1150	8.5	1.60
6	1380	10.2	1.92
7	1610	11.9	2.24
8	1840	13.6	2.56
9	2070	15.3	2.88
10	2300	17.0	3.20

***Source: Midwest Laboratories, "Agronomy Handbook".**

Once we have replaced the sodium with calcium, we must remove the sodium from the rooting zone. This is done by leaching the sodium sulphate out of the root zone by watering. The levels of water required to leach out free sodium is as follows:

- 6 inches of water per foot of root zone will remove 50%
- 12 inches of water per foot of root zone will remove 80%
- 24 inches of water per foot of root zone will remove 90%

Soil Crusting and Compaction:

Both alkali and saline-alkali soils can exhibit crusting and soil compaction conditions. Problems arising from crusting and soil compaction can and will show themselves in crops. Deficiency of phosphorus and micronutrients can be most evident in these conditions.

Soil crusting can be caused by the following:

1. High Na
2. Pulverizing dry soils
3. Heavy water application
4. Low OM soils
5. Water high in sodium and bicarbonates

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Solutions to Soil Crusting:

1. Till soil at good moisture levels
2. Use **Tiger 90 CR Sulphur**
3. Use acid forming fertilizers
4. Humic acids

The above solutions to soil crusting are the same as we have been talking about with respect to soil amendments in alkali soils. The root cause to both problems is high pH; by lowering the pH we can increase soil tilth. In order for this to happen we do need free lime present in the soil. Once pH is lowered the calcium from the free lime will adhere to the clay colloid. Calcium must be present in excess of 20 PPM in order for good soil flocculation to take place.

How Tiger 90CR can be used as a soil amendment:

As Tiger 90CR degrades into a fine powder and is converted from elemental sulphur to plant available sulphate, sulphuric acid is released. The sulphuric acid will then react with the free lime in the soil creating carbonic acid and gypsum. The gypsum created by the oxidation of Tiger 90CR Sulphur will help with the flocculation of the soil.

Soil flocculation is caused by the Calcium, from the gypsum, and the clay colloid interacting in a cation exchange reaction in which the positively charged calcium ions will adhere to the negatively charged clay colloid. Thus giving the soil more tilth and reduce the soil crusting.

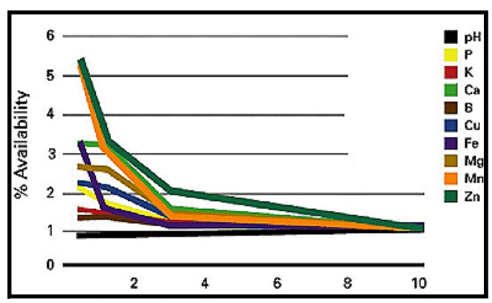
Along with the softening of the soil, Tiger 90CR Sulphur will also help to reduce the salting problem associated with calcareous soils. Calcium will kickoff sodium from the clay colloid and into the soil solution where it can be leached out.

There are three steps involved in the use of Tiger 90CR Sulphur as a soil amendment for Sodic soils, they are as follows:

1) Tiger 90CR + O_2 + H_2O -------------------- Sulphuric Acid
2) Sulphuric Acid + Free Lime -------------------Gypsum + CO_2 + H_2O
3) Gypsum + Sodic soil -------------------------Calcium soil + sodium sulphate

The benefits to using Tiger 90CR as a soil amendment are as follows:

1. **Release of Phosphate and micronutrients**
2. **Forms gypsum**
3. **Less crusting**
4. **Faster water penetration**
5. **Faster water runoff**
6. **Removes sodium**
7. **Better aeration of soil**



Nutrient availability increases as you move closer to the Tiger 90CR Sulphur prill, this is the result of the formation of sulphuric acid as the Tiger 90CR Sulphur oxidizes thus reducing the pH in the micro site.

Conclusions:

What is meant by soil amending? Simply put it is the process of adding a material to the soil to change and improve the characteristics of that soil and aid plant growth. The above discussion gives us ideas and recommendations to follow, when trying to change the characteristics of alkali and saline-alkali soils.

Along with the ideas presented in this paper, we discussed the advantages to using Tiger 90CR Sulphur in a soil amending role and how this is done. ***By using Tiger 90CR Sulphur as a pH and soil amendment tool we can flocculate the soil by releasing calcium into the soil. This is done by converting the free lime, present in almost all western soils, to gypsum and thus exchanging calcium for sodium on the clay colloid.***

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Alkali and saline-alkali soils are characterized by the replacement of calcium and magnesium on the soil particle by sodium. There may also be an excessive accumulation of soluble salts in the soil. As the proportion of absorbed sodium increases, alkali soils tend to become highly dispersed and impermeable to water and air. Excessive sodium is also toxic to crops.

The action of Tiger 90 CR and sulphur compounds on these soils is either to supply calcium or release insoluble calcium already present. The calcium replaces the absorbed sodium on the clay particles. The sodium combines with the sulphate ion to form soluble sulphate which is removed through leaching.

The result of implementing Tiger 90CR sulphur as a soil amendment tool will be greater nutrient availability and plant growth, thus improving crop yield, quality and profitability.

FREE LIME RATES

% Lime	Evaluation
0 - 0.25	Very Low
0.25 - 0.5	Low
0.5 - 2.9	Medium
3.0 - 8.0	High
8.1 +	Very High

Source: John P. Taberna. Soil Scientist, Parma Idaho.

Approximate pounds of S (based on 99% S) needed to lower the soil pH of one acre-foot of soil

Pounds of sulfur required per acre			
Change in pH	Sand	Loam	Clay
8.5 - 6.5	3500	4375	5250
8.0 - 6.5	2450	2625	3500
7.5 - 6.5	875	1400	1750
7.0 - 6.5	175	275	525

Source: *John. P. Taberna,. Soil Scientist, Parma Idaho.*

Tiger 90CR Amended Potato field
University of Idaho

Glossary of Terms:

Sodium:

An excess of sodium causes the soil to exhibit alkali conditions such as soil crusting, slow water intake, and poor aeration. These conditions reduce the yield capability of the soil. The sodium percentage can be reduced by adding gypsum or various sulphur products.

Excess Lime (Calcium Carbonate):

An excess of lime (1.0 or more) will reduce the availability of phosphorus and micronutrients and will cause the soil to crust. An excess of lime can also decrease the decomposition of some herbicides. Nearly all soils with an excess of lime will have pH values between 7.0 and 8.4. The application of elemental sulphur or acid forming fertilizers can improve the overall detrimental effects of excess lime. Many western soils contain between 4 and 8% excess lime and some contain 15 – 20%.

Calcium:

Calcium is an essential nutrient and is usually found in soil as excess lime and gypsum. Calcium must be present in excess of 20 PPM in order for good soil flocculation to take place. This assumes low levels of carbonates and bicarbonates. High levels of carbonates and bicarbonates require higher levels of calcium in order for retention of good physical properties.

Soil pH:

Soil pH refers to the acidity or alkalinity of the soil with a pH of 7.0 being neutral, and pH below 7.0 being acid, and a pH above 7.0 being alkaline, and a pH above 8.4 being alkali because of excess sodium. Most soils will have a pH of between 5 and 8.4, and soils with a pH above 7.0 will usually have an excess of undissolved free lime.

The optimum pH for most plants is between 6.5 and 7.5, and pH's below 6.0 require lime for best growth. A pH below 6.0 will cause phosphorus to be unavailable and the micronutrients Zn, Fe, Cu, Mn, and B.

pH:

Soil pH refers to the acidity or alkalinity of a soil. A pH above 7.0 is alkaline and below 7.0 is acid. A neutral pH is for all practical purposes between 6.7 and 7.3. The most desirable pH for most crops us between 6.3 and 7.5. pH's above 8.4 almost always indicate a strongly alkali problem. Soils with pH's below 6.2 almost always need an application of agricultural liming material.

Elemental Sulfur:

Elemental sulphur may be recommended in several situations. If available iron is low, elemental sulphur is recommended to help acidify the soil and make more iron available. Elemental sulphur is also recommended whenever sodium is present is excess and there is an excess of lime. Gypsum can be substituted for elemental sulphur using a ratio of about 6 lbs. of gypsum to 1 lb. of elemental sulphur.

Compaction:

Compaction reduces the degree of aeration by decreasing the pore sizes in the root zone of the growth media. This in turn restricts root growth and reduces absorption of phosphorus and other nutrients.

Sodic soils:

Term used in reference to alkali soils. Theses are soils that are generally sodium-saturated in a dispersed of deflocculated condition. In this condition the water cannot or is impaired from entering the soil.

Works Cited:

Stukenholtz. Agronomic Training Manual. Twin Falls, Idaho.

Western Laboratories Canada. Agronomy Handbook. Calgary, Alberta.

Taberna, John. P. Tiger-Sul Products. Training Handout. Parma, Idaho.