Agronomic Technical Bulletin

Amending Soil with Tiger 90CR® Sulphur

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The world population continues to increase and demand for quality food supply increases. Several factors have contributed to significant increases in crop production, which includes improved hybrids/varieties, technology, and plant nutrient management. Maximizing crop yield potential on each acre/hectare requires attention to details. The scope of this discussion will focus on soil conditions and adding amendments to enhance plant nutrient availability. Soil amendments are materials added to soil to improve its characteristics that are more conducive to root growth and enhance nutrient uptake. Soil conditions that are predominant in western North America, but occur to lesser extent in other areas include alkaline, saline, sodic, and saline/sodic soils (**Table 1.0**).

Table 1.0 Classification of adverse soil conditions

Classification	Electrical Conductivity (mmhos/cm)	Soil pH	Sodium Absorption Ratio (SAR)[1]	Soil Physical Condition
Slightly Saline	2-4	< 8.5	< 13	Normal
Saline	> 4.0	< 8.5	< 13	Normal
Sodic	< 4.0	> 8.5	> 13	Poor
Saline - Sodic	> 4.0	< 8.5	> 13	Varies
Alkaline - High pH	< 4.0	> 7.8	< 13	Varies

1 - If reported as exchangeable sodium percentage (ESP), use 15% as threshold value.
Source: R. M. Waskom & et al. 2012. Diagnosing Saline and Sodic Soil Problems.
Fact Sheet 521 Colorado State University Extension.

Some basic definitions to better understand the various issues:

1) alkaline soil – high soil pH > 7.5
2) saline soil – high salt content
3) sodic soil – high sodium content
4) saline/sodic soil – high salt and high sodium content

Each of these soil conditions has specific causes and symptoms that result in adverse affects to plant growth (**Table 2.0**). Oftentimes, these soil conditions are confused, so a correct diagnosis is critical to a successful outcome. The best diagnostic tool to confirm a specific soil problem is a soil sample analysis.

Table 2.0 Diagnosing high pH, saline, or sodic soil problems

Problem	Potential Symptom
Alkaline - High pH	Nutrient deficiencies manifested as stunted, yellow plants, Dark green – purplish plants
Saline soil	White crust on soil surface, water stressed plants, leaf tip burn
Saline irrigation water	Leaf burn, poor growth, moisture stress
Sodic soil	Poor drainage, black powdery residue on soil surface
Saline - sodic soil	Generally, same symptoms as saline soil

Source: R. M. Waskom & et al. 2012. Diagnosing Saline and Sodic Soil Problems. Fact Sheet 521 Colorado State University Extension.

Alkaline Soils

Multiple research reports have supported the conclusion that soil pH directly influences availability of plant nutrients from the soil. Optimum nutrient uptake by most plants occurs between soil pH range of 6.0 – 7.0. **Chart 1.0** illustrates the relationship of soil pH and relative availability of plant nutrients. The width of the bars in chart represents potential nutrient availability. Some crops prefer soil pH below 6.0 including blueberries, brambles, cranberries, potatoes, and sweet potatoes. There are crops that prefer soil pH above 7.0 which include alfalfa, soybeans, and several vegetable crops. When soil pH rises above 7.5 it is referenced as an alkaline condition.

Frequently, nutrient deficiency symptoms are displayed by crops grown in soils with a pH greater than 7.5. Availability of most essential nutrients is limited as soil pH increases above 7.5. Plant nutrient deficiencies under these conditions can be managed temporarily by foliar nutrient application and for a longer term by reducing soil pH. Soil pH may be lowered with the application of elemental sulphur (**TIGER 90CR**). Application rate is a function of soil texture (**Table 3.0** - next page).

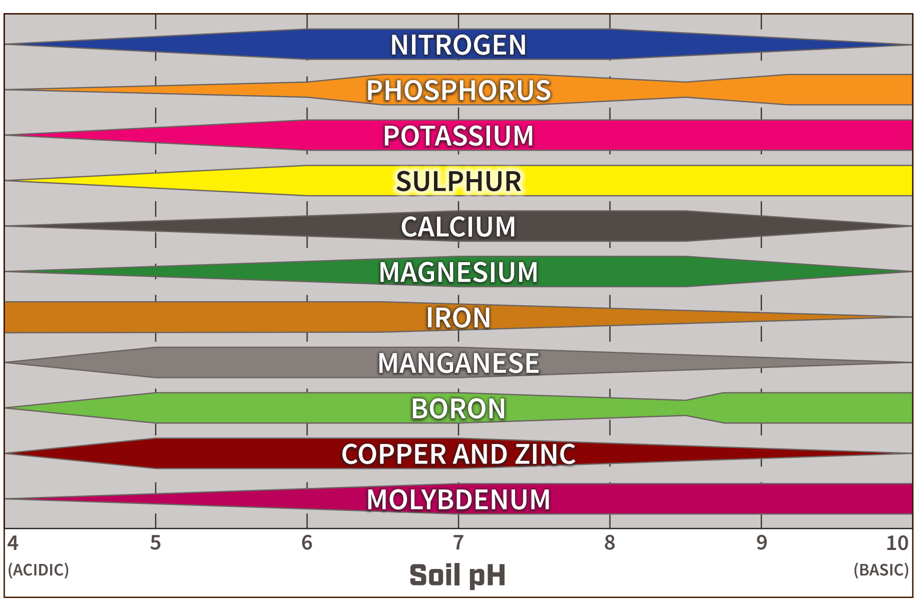
The sulphur (S) oxidation process is the conversion of elemental S to sulphate (SO_4). The chemical reaction is biologically driven as shown in following reaction equations:

$$S + O_2 + H_2O \xrightarrow{BACTERIA} H_2SO_4$$
$$CaCO_3 + H_2SO_4 \xrightarrow{BACTERIA} CaSO_4 + H_2CO_3$$
$$CaSO_4 \longrightarrow Ca^{+2} + SO_4^{-2}$$
$$H_2CO_3 \longrightarrow H_2O + CO_2$$

The reaction of elemental sulphur with water, oxygen, and bacteria forms sulphuric acid. Sulphuric acid (H_2SO_4) reacts with calcium carbonate ($CaCO_3$) in soil to form calcium sulphate ($CaSO_4$, gypsum) and carbonic acid (H_2CO_3). In soil moisture the calcium sulphate dissociates into Ca and SO_4 . The carbonic acid dissociates into water and carbon dioxide. From these reactions sulphuric acid is formed and the SO_4 is plant available.

When **TIGER 90CR** sulphur is soil applied and goes through an oxidation process, sulphuric acid and hydrogen (H^+) ions are released, soil is acidified and pH is lowered. Since sulphur oxidation is a biological process, this activity will vary among soil types. **Table 3.0** should be utilized as a starting point as individual situations are unique and may require more or less than the values provided. Collect soil samples one year after sulphur application to evaluate progress in adjusting soil pH.

Chart 1.0



Adapted from Truog, 1946. SSAP 11:305-308

Saline Soils

Saline soils contain excess soluble salts, which interfere with the plants ability to absorb water and nutrients. Most crops are more sensitive to salt injury during germination and seedling growth stages. The source of salts is a function of soil parent material, soil drainage, and weather conditions over time. These salts tend to accumulate in soil as water evaporates, especially in arid areas. Oftentimes, excess salts will crystallize on soil surface leaving a white residue.

Determination of soluble salts present is done by measuring the electrical conductivity (EC) of soil solution from a saturated paste soil sample. The units of measurement are "mmhos/cm". The salt content is proportional to the EC of the soil solution. A general guideline for evaluating soil test results is provided in **Table 4.0**.

Table 3.0 Elemental sulphur, incorporated 6 inches deep, required to decrease soil pH

Application rate based on soil texture[1]			
Desired change in pH	Sand	Silt Loam	Clay
	lbs. S/Ac		
8.5 to 6.5	370	730	1460
8.0 to 6.5	340	670	1340
7.5 to 6.5	300	600	1200
7.0 to 6.5	180	360	720
8.5 to 5.5	830	1669	3310
8.0 to 5.5	800	1600	3190
7.5 to 5.5	760	1530	3050
7.0 to 5.5	640	1290	2580

[1] Assumptions – cation exchange capacity of the sandy, silt loam, and clay soils are 5, 10, and 15 meq/100 g, respectively; soils are not calcareous.
Source: Robert Mullen & et al. 2012. Soil Acidification: How to Lower Soil pH. Fact Sheet AGF-507-07. Ohio State University Extension.

Reclamation of saline soils can only be accomplished by removing the accumulated salts from the root zone. Three methods have proved successful in managing saline soils. All three methods utilize water to move the salts and they include: 1) leaching, 2) artificial drainage, and 3) managed accumulation. Leaching involves applying more water than required by crop to move salts below the root zone. Artificial drainage utilizes the leaching method to move salts to sub-surface drainage tiles to carry salt and water away from the field. Managed accumulation is the movement of salts from the immediate root zone to areas such as every other row middle, field edges, etc., that reduces potential harmful effects. Sequential applications of water should be added so that sufficient time for drainage is allowed between applications. Quantity of water needed for salt removal is dependent on beginning salt level in the soil, the desired salt level, quality of irrigation water, and method of water application. Generally, expect to use approximately 8-10 inches (20-25 cm) of water to remove approximately 70% of soluble salts per 12 inches (30 cm) of soil to be leached.

Sodic Soils

Soils that contain high sodium (Na) and low total salts are referred to as sodic soils. These soils tend to crust and are cloddy when dry. Sodium causes the soil particles to disperse and results in poor soil structure and minimizes water infiltration. A soil sample analysis for Na and soluble salts will identify the specific problem. The extent of Na severity is expressed as sodium adsorption ratio (SAR). This ratio provides the proportion of water soluble Na to calcium and magnesium in soil. (**Table 1.0**) When the soil exceeds a SAR of 13, options for removing the Na need to be evaluated. Oftentimes, switching to a more tolerant crop is not an option, and the soil must be altered to create a more favorable environment for plant growth.

Table 4.0 Interpretation of Electrical Conductivity (EC)

EC (mmhos/cm)	Salt Rank	Interpretation
0-2	Low	Very little chance of plant injury
2-4	Moderate	Sensitive plants and seedlings of others may show injury
4-8	High	Most non-salt tolerant plants will show injury
8-16	Excessive	Salt tolerant plants will grow, most others severe injury
16+	Very Excessive	Very few plants will tolerate and grow

Source: R.E. Lamond and D.A. Whitney. Kansas State University. Fact Sheet MF 1022

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Sodic soils can be reclaimed by applying an amendment that will result in the displacement of Na from the soil cation exchange complex and replaced with calcium (Ca). When Na has been displaced, it can be leached out of the rooting zone with rainfall and/or irrigation. **Tiger 90CR** sulphur can be an effective amendment to displace Na if the soil has greater than 1% free lime (calcium carbonate, $CaCO_3$). The sulphur is converted to sulphuric acid through microbial oxidation. The sulphuric acid then reacts with lime ($CaCO_3$) in the soil to form calcium sulphate (gypsum, $CaSO_4$). Then the $CaSO_4$ will dissolve in soil water and the Ca will react to displace the Na. **Tiger 90CR** has a high efficiency ratio due to its 90% sulphur concentration and clay content that enhances the soil reaction. As shown in **Table 5.0**, **Tiger 90CR** sulphur requires 75% less material to provide an equal amount of Ca to displace Na from the soil exchange complex. Should a sodic soil not contain free $CaCO_3$, then $CaSO_4$ would be the product of choice to supply Ca to displace the Na and move it out of the rooting zone by leaching. Reclaiming a sodic soil can be a slow process as soil structure damage is slow to improve.

Table 5.0 Soil amendments required to supply 1 lb of soluble calcium

Amendment	Purity %	Pounds
Sulphur	99.5%	0.8
Tiger 90CR Sulphur	90%	1.1
Sulphuric Acid	95%	2.6
Calcium Chloride	100%	3.7
Gypsum	100%	4.3

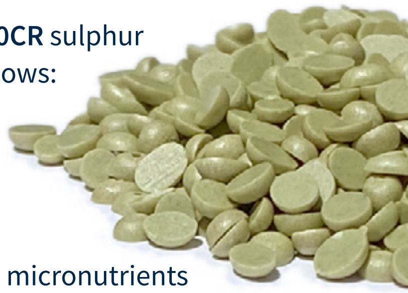
Source: Adapted from J.G. Davis & et al. 2012. Managing Sodic Soils. Fact Sheet 504. Colorado State University Extension.

Saline-Sodic Soils

These soils contain high levels of soluble salts and high exchangeable sodium content (> 13 SAR). The physical properties of these soils reflect saline characteristics. To improve these soils, amendments and drainage are essential. Adding sufficient water to leach a saline-sodic soil without amendments will result in a sodic soil and may worsen the soil structure. Therefore, leaching of soluble salts must be followed by or preceded by the displacement of exchangeable Na with Ca.

Summary:

Benefits to employing **TIGER 90CR** sulphur as a soil amendment are as follows:



1) Removes sodium
2) Forms $CaSO_4$
3) Faster water infiltration
4) Improved soil aeration
5) Release of phosphate and micronutrients
6) Most beneficial in alkaline or sodic situations

Soil characteristics vary from field to field and farm to farm; therefore, they require management adjustments. All soils should be evaluated individually with respect to the management needed to minimize yield limiting factors. Future yields are dependent upon current production practices to conserve and improve soil productivity.

References:

Davis, J.G. & et al. 2012. Managing Sodic Soils. Fact Sheet 504. Colorado State University Extension.

Lamond, R. E. and D. A. Whitney. 1992. Management of Saline and Sodic Soils. Fact Sheet MF 1022, Kansas State University Extension.

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Tisdale, S.L. & et al. 1985. Soil Fertility and Fertilizers, Fourth Edition. Macmillan Publishing Co. New York.

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