CHEMICAL AMENDMENTS

for Improving Sodium Soils

(CaCO₃)  
(H₂SO₄)  
(CaSO₄ • 2H₂O)  
(CaCl₂ • 2H₂O)  
(S)  
(S)

(TED STATES DEPARTMENT OF AGRICULTURE

Culture Information
Bulletin No. 195
CONTENTS

How do amendments work? .......................... 1
What are the chemical amendments for sodium soils? .......................... 3
Does your soil need a chemical amendment? .......................... 4
What kind of amendment should be applied? .......................... 5
How should the cost of amendments be compared? .......................... 6
How much amendment should be applied? .......................... 6
How should amendments be applied? .......................... 7
Points that deserve emphasis .......................... 8

This Bulletin—

1. Describes chemical amendments and their action on sodium soils.
2. Gives information on determining the need of soils for amendments.
3. Discusses the suitability, application rates, and methods of application of various amendments.

Bower, Charles Arthur, 1916–

Chemical amendments for improving sodium soils.
9 p. illus. 24 cm. (U. S. Dept. of Agriculture. Agriculture information bulletin no. 195)

3. Soils. 2, 3. Soil, Sodium in. I. Title. (Series)
S21.A74 no. 195 631.8 Agr 59–2
U. S. Dept. of Agr. Libr. 1Ag84Ab no. 195
for Library of Congress †

Washington, D. C. Issued January 1959

For sale by the Superintendent of Documents, U. S. Government Printing Office
HOW DO AMENDMENTS WORK?

Amendments supply soluble calcium for the replacement of sodium attached to soil particles.

Soil particles have negative electrical charges at their surfaces, and they absorb (attract and hold) positively charged salt constituents called cations. The common cations are calcium, magnesium, and sodium. Calcium and magnesium are the principal cations found in normal, productive soils, and they have a favorable effect upon the physical condition of the soil. If soils have come in contact with high-sodium irrigation or ground waters, they usually contain adsorbed sodium as well adsorbed calcium and magnesium. Adsorbed sodium has a detrimental effect upon soil.

Each soil has a reasonably definite capacity to adsorb cations. The percentage of this capacity that is taken up by sodium is called the exchangeable-sodium-percentage. When the exchangeable-sodium-percentage exceeds 10 to 20, the soil develops a poor physical condition, especially if the soluble-salt content is low. Coarse-textured soils can tolerate a higher exchangeable-sodium-percentage than fine-textured soils before the physical condition deteriorates. Also, soils having a high content of organic matter can tolerate a higher exchangeable-sodium-percentage than soils having a low organic matter content.

Although the adsorbed cations in soils are united chemically with the soil particles, they may be replaced by, or exchanged with, other cations dissolved in the soil water. The purpose of applying chemical amendments is to supply calcium in the soil water for the replacement of adsorbed sodium.
When irrigation water and an amendment that supplies soluble calcium are applied to a sodium soil having dispersed particles and small pores, the calcium replaces the adsorbed sodium and permits the particles to aggregate so as to form large pores. The aggregation of calcium soil is facilitated by alternate wetting and drying, and by the action of growing plant roots.
WHAT ARE THE CHEMICAL AMENDMENTS FOR SODIUM SOILS?

Gypsum and sulfur are the chemical amendments most commonly used to improve sodium soils.

Other amendments less commonly used are calcium chloride, limestone, sulfuric acid, iron and aluminum sulfates, and lime-sulfur. All of these amendments, when used under the proper soil conditions, have one characteristic in common—they supply soluble calcium.

**Gypsum** (calcium sulfate dihydrate) is a white mineral that occurs extensively in natural deposits. Usually, it must be ground before it is applied to soils. Gypsum is soluble in water to the extent of about one-fourth of 1 percent and is, therefore, a direct source of soluble calcium. It may be purchased in mine-run grades, which may be less than 50 percent pure, or in quality grades having a purity of 95 percent or more. The degree of fineness influences the rate at which gypsum goes into solution. In a high grade of gypsum, at least 75 percent of the particles should pass a 100-mesh sieve.

**Sulfur** for application to soils is a yellow powder ranging in purity from 50 percent to more than 99 percent. It is not soluble in water and does not supply calcium directly. When applied to soils, sulfur is slowly oxidized by micro-organisms in the presence of air and water to sulfuric acid. If lime is present in the soil, it reacts with the sulfuric acid to form gypsum and small amounts of calcium bicarbonate. The gypsum and calcium bicarbonate are sources of soluble calcium. Finely ground sulfur will react more quickly in the soil than will coarsely ground material, but the latter is easier to apply and is less irritating to the skin and eyes.

**Calcium chloride** (road salt) is a highly soluble salt, which supplies soluble calcium directly. Its degree of purity is generally in excess of 95 percent.

**Limestone** (calcium carbonate) occurs as a deposit in many places and must be ground for use as a soil amendment. It is practically insoluble in alkaline soils but it goes into solution slowly in acid soils. The rate at which it goes into solution and supplies soluble calcium depends upon the degree of fineness. Waste lime from sugar factories is a desirable source of calcium carbonate for application to soils because the particles are fine. Limestone is sometimes applied to lime-free soils, along with acid or acid-forming amendments.

**Sulfuric acid** is an oily, corrosive liquid, and is usually about 95 percent pure. Upon application to soils containing lime, it immediately reacts with the lime to form gypsum, and thus provides soluble calcium indirectly.

**Iron sulfate** (copperas) and **aluminum sulfate** (alum) are solid, granular materials, which usually have a high degree of purity and are
soluble in water. When applied to soils, they dissolve in the soil water and decompose to form sulfuric acid, which in turn supplies soluble calcium through its reaction with lime.

**Lime-sulfur** (calcium polysulfide) is a yellowish-brown, alkaline liquid, which usually contains about 24 percent of sulfur. The calcium content is ordinarily about one-fourth that of sulfur, and the action of lime-sulfur in soils depends mainly on the sulfur content. Like free sulfur, it must first be oxidized to sulfuric acid, and then react with lime to produce a soluble form of calcium.

**DOES YOUR SOIL NEED A CHEMICAL AMENDMENT?**

*I may, if it is in poor physical condition, or if it is saline.*

The positive way to determine the need for an amendment is to have chemical soil tests made for adsorbed sodium.

Soils in poor physical condition take water slowly, crust badly on drying, and are difficult to till. If the condition is caused by the presence of sodium adsorbed (attached) on the soil particles, the application of an amendment will be beneficial. Some soils that contain practically no adsorbed sodium are in poor physical condition because of a high clay content, or a lack of organic matter, or because they have been cultivated while wet. These soils are not benefited by the application of amendments.

Many saline soils contain an excess of adsorbed sodium and yet may have a satisfactory physical condition because of the presence of soluble salts. However, when the soluble salts are removed by leaching, the adsorbed sodium usually remains, and causes the physical condition of the soil to deteriorate unless an amendment has been applied.

The presence of adsorbed sodium is indicated if a black deposit of organic matter appears on the soil surface upon drying, but the only sure way to detect excess adsorbed sodium is by having chemical tests made of soil samples. Your county farm adviser, local Soil Conservation Service technician, or a commercial laboratory can assist you in obtaining soil samples and in having tests made. Ask that your soil be tested for adsorbed (exchangeable) sodium. If appreciable adsorbed sodium is present, the soil samples should also be tested for gypsum and lime contents and for pH value. Sometimes sodium soils naturally contain enough gypsum to replace the adsorbed sodium upon leaching, and no amendment need be applied. Information on the presence or absence of lime in the soil and the pH value is needed because it determines the kind of amendment that can be applied.
WHAT KIND OF AMENDMENT SHOULD BE APPLIED?

The selection of an amendment is influenced by—

1. The lime content and the pH reading of the soil.
2. The time required for the amendment to react in the soil.
3. The cost of the amendment per unit of soluble calcium which it supplies either directly, or indirectly by reaction with lime in the soil.

Any of the amendments described, except limestone, may be used on sodium soils containing lime. The addition of limestone to sodium soil already containing lime will be of no value. The application of sulfur, sulfuric acid, lime-sulfur, and iron and aluminum sulfates to soils containing no lime tends to make them acid. When the amounts of these acid, or acid-forming, amendments needed would make the soil excessively acid (pH 6 or less), the choice of amendment is limited to gypsum or calcium chloride, unless limestone also is applied. The application of limestone alone to lime-free sodium soils tends to be beneficial, but its effectiveness is not great unless the pH reading is 7 or less.

Unfortunately, the cheaper amendments are slower to react than the more expensive. Because of its high solubility in water, calcium chloride is probably the most readily available source of soluble calcium, but it is seldom used because of its high cost. Sulfuric acid and iron and aluminum sulfates are also quick-acting amendments. Sulfuric acid is often cheap enough for field application, but the use of iron and aluminum sulfates is usually too costly. Because of their relatively low cost, gypsum and sulfur are the amendments most commonly used. The rate of reaction of gypsum is limited only by its moderate solubility. Under field conditions, the application of 3 to 4 acre-feet of irrigation water is required to dissolve 4 or 5 tons of high-grade gypsum.

Because sulfur must first be oxidized to sulfuric acid by soil microorganisms before it is available for reaction, it is a slow-acting amendment. The sulfur in lime-sulfur must also be oxidized, but the reaction is somewhat faster than when free sulfur is applied because the lime-sulfur is applied in solution. Lime-sulfur is one of the more expensive amendments. Limestone is relatively cheap, but it is only occasionally useful as most sodium soils already contain lime. Unless the soil is decidedly acid, the reaction of limestone is slow.
HOW SHOULD THE COST OF AMENDMENTS BE COMPARED?

The relative cost of amendments should be determined on the basis of the amount of soluble calcium which they supply either directly or indirectly by reaction with lime in the soil.

The following table gives the amounts of various amendments required to supply 1,000 pounds of soluble calcium when applied under the proper soil conditions. In most cases, the values given are for 100-percent-pure amendments.

**Amounts of various amendments required to supply 1,000 pounds of soluble calcium**

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Purity 1</th>
<th>Pounds required to supply 1,000 pounds of soluble calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gypsum (CaSO₄·2H₂O)</td>
<td>100</td>
<td>4,300</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>100</td>
<td>800</td>
</tr>
<tr>
<td>Calcium chloride (CaCl₂·2H₂O)</td>
<td>100</td>
<td>3,700</td>
</tr>
<tr>
<td>Limestone (CaCO₃)</td>
<td>100</td>
<td>2,500</td>
</tr>
<tr>
<td>Sulfuric acid (H₂SO₄)</td>
<td>95</td>
<td>2,600</td>
</tr>
<tr>
<td>Iron sulfate (FeSO₄·7H₂O)</td>
<td>100</td>
<td>6,950</td>
</tr>
<tr>
<td>Aluminum sulfate (Al₂(SO₄)₃·18H₂O)</td>
<td>100</td>
<td>5,550</td>
</tr>
<tr>
<td>Lime-sulfur solution</td>
<td>24</td>
<td>3,350</td>
</tr>
</tbody>
</table>

1 If the amendment has a purity different from that indicated above, determine the amount needed to supply 1,000 pounds of soluble calcium by dividing the percentage of purity given in the table by the percentage of purity of the material to be applied, and multiply this value by the number of pounds shown in the table. For example, if limestone having a purity of 75 percent is used, the calculation would be: \((100 ÷ 75) \times 2,500 = 1.33 \times 2,500 = 3,330\) pounds.

2 Because lime-sulfur solutions have indefinite chemical compositions, their purity is expressed in terms of sulfur content.

HOW MUCH AMENDMENT SHOULD BE APPLIED?

The amount of an amendment that should be applied depends primarily upon the adsorbed sodium content of the soil and the amount of soluble calcium that the amendment supplies per unit of weight. Other factors to consider are the quality of the irrigation water and soil texture.

From the results of chemical soil tests for adsorbed sodium, a qualified agriculturist can calculate the approximate amount of soluble...
calcium required per acre to remove the adsorbed sodium from a given depth of soil. However, it is usually not practical, or even necessary, to remove all of the adsorbed sodium from the root zone of soils by the application of an amendment. Soils, especially if they are coarse-textured, can tolerate some adsorbed sodium without noticeable effect on their physical condition, and the use of irrigation water of good quality can be depended upon to remove excess adsorbed sodium gradually. An irrigation water of good quality, from the standpoint of removal of adsorbed sodium, is one that contains a considerable amount of calcium plus magnesium, and has a calcium-plus-magnesium to sodium ratio of one or more.

A common practice is to apply sufficient amendment to remove most of the adsorbed sodium from the top 6 to 12 inches of soil. This improves the physical condition of the surface soil within a short time and permits the growing of crops. By the continued use of good irrigation water, and good irrigation and cropping practices, further removal of adsorbed sodium, especially in the subsoil, usually takes place.

As a general rule, fine-textured sodium soils have higher soluble-calcium requirements than coarse-textured soils. Usually, to obtain a noticeable improvement in the physical condition of the soil, sufficient amendment to supply at least 1,000 pounds of soluble calcium per acre must be applied to coarse-textured soils, and enough to supply 2,000 pounds per acre to fine-textured soils. Application rates sufficient to supply 2,000 to 4,000 pounds of soluble calcium per acre are common. Unless crops of very high value are to be grown, the application of amounts of amendments which supply more than 5,000 to 6,000 pounds of soluble calcium per acre is seldom practical.

Your county farm adviser or a Soil Conservation Service technician should be consulted for local experience on rates of application of amendments. After deciding the kind of amendment to be used and the amount of soluble calcium to be supplied per acre, use the table on p. 6 to convert pounds of soluble calcium to pounds of the kind of amendment selected.

HOW SHOULD AMENDMENTS BE APPLIED?

Gypsum, calcium chloride, sulfuric acid, and iron and aluminum sulfates are usually applied directly to the soil, but they may also be applied in the irrigation water. Sulfur and limestone must be applied to the soil directly in pulverized form. Lime-sulfur is usually applied in the irrigation water.

Gypsum, sulfur, calcium chloride, limestone, and iron and aluminum sulfates are normally applied broadcast and then incorporated into the soil by plowing or disk ing. Thorough incorporation to insure a satis-
factory rate of reaction is especially important when sulfur is applied. Because of hazards in handling, sulfuric acid is usually applied by the supplier, who uses special equipment to spray the acid on the soil surface.

Except where sulfur is employed, sodium soils should be leached following the application of amendments. Leaching dissolves and carries the amendment downward, and also removes the soluble sodium salts that form as the adsorbed sodium is replaced by calcium. When sulfur is applied, 2 or 3 months should elapse before leaching in order that the amendment may oxidize and form gypsum. However, the soil should be kept moist because water is essential for sulfur oxidation.

In saline soils, more adsorbed sodium will be removed if the soil is leached before, as well as after, the amendment is applied. However, it is nearly always best to apply the amendment before leaching, because the water-intake rate of saline-sodium soils generally decreases greatly if soluble calcium is not present or supplied as the soluble salts are leached out.

It is sometimes convenient to apply those amendments that are water soluble in the irrigation water. Special equipment is available for metering both liquid and solid amendments into irrigation water. A simple method of applying gypsum in irrigation water consists of placing a bag of the amendment with the side slit open in the irrigation ditch, preferably at a weir where the water has considerable turbulence. Because gypsum has a limited solubility, it is not practical to apply this amendment in the irrigation water if large amounts are needed by the soil.

POINTS THAT DESERVE EMPHASIS

1. Test—don’t guess.
2. Take soil samples with care.
3. Don’t expect immediate results from amendments.
4. Amendments are not cure-alls.

Because the application of amendments usually involves considerable expense, it is sound practice to determine the kind and amount of amendment on the basis of chemical soil tests. It is worthwhile to have your soil tested every year or two, especially if an amendment has been applied, to determine whether adsorbed sodium is decreasing or increasing.

The value of a soil test depends upon how well the soil sample represents field conditions. Because soils affected by sodium vary considerably from place to place in a field, it is usually necessary to obtain several composite samples within the field to determine the range of soil conditions.
After the adsorbed sodium is removed, the soil particles must rearrange and clump together in granules before the physical condition of the soil improves. This process takes time and is brought about by alternate wetting and drying, by the action of growing plant roots, and by organic matter.

The application of an amendment is not a substitute for good soil and water-management practices. Applications of amendments may be largely ineffective unless the soil is periodically leached and unless the ground-water table remains at a sufficient depth to prevent appreciable upward movement of water and salts. If the irrigation water contains a high proportion of sodium and continually adds adsorbed sodium to the soil, periodic applications of amendments will be needed.