

Managing Soil Salinity

Tony Provin and J.L. Pitt*

If your soil has a high salinity content, the plants growing there will not be as vigorous as they would be in normal soils. Seeds will germinate poorly, if at all, and the plants will grow slowly or become stunted. If the salinity concentration is high enough, the plants will wilt and die, no matter how much you water them.

Routine soil testing can identify your soil's salinity levels and suggest measures you can take to correct the specific salinity problem in your soil.

Salinity and salt

The terms salt and salinity are often used interchangeably, and sometimes incorrectly. A salt is simply an inorganic mineral that can dissolve in water. Many people associate salt with sodium chloride—common table salt. In reality, the salts that affect both surface water and groundwater often are a combination of sodium, calcium, potassium, magnesium, chlorides, nitrates, sulfates, bicarbonates and carbonates (Table 1).

These salts often originate from the earth's crust. They also can result from weathering, in which small amounts of rock and other deposits are dissolved over time and carried away by water. This slow weathering

may cause salts to accumulate in both surface and underground waters. The surface runoff of these dissolved salts is what gives the salt content to our oceans and lakes. Fertilizers and organic amendments also add salts to the soil.

Effects of salts on plants

As soils become more saline, plants become unable to draw as much water from the soil. This is because the plant roots contain varying concentrations of ions (salts) that create a natural flow of water from the soil into the plant roots.

As the level of salinity in the soil nears that of the roots, however, water becomes less and less likely to enter the root. In fact, when the soil salinity levels are high enough, the water in the roots is pulled back into the soil. The plants become unable to take in enough water to grow. Each plant species naturally contains varying levels of root salts. This is why some plants can continue to thrive when others have died.

If the salinity concentration in the soil is high enough, the plant will wilt and die, regardless of the amount of water applied. Figure 1 shows how the various salt concentrations affect the movement of water from the soil to plants.

Salt buildup

Salinity is of greatest concern in soils that are:

- Irrigated with water high in salts;
- Poorly drained, allowing for too much evaporation from the soil surface;
- Naturally high in salts because very little salt leaches out;
- In areas where the water table (the level or depth to free-flowable water in the soil) is shallow; or
- In seepage zones, which are areas where water from other locations (normally up slope) seep out.

The major source of salinity problems is usually irrigation water. This is a gradual process—the salts must accumulate over time before any effects are

Common Name	Chemical Name	Chemical Formula
Table salt	Sodium chloride	NaCl
Glauber's salt	Sodium sulfate	Na ₂ SO ₄
Baking soda	Sodium bicarbonate	NaHCO ₃
Epsom salt	Magnesium sulfate	MgSO ₄
Gypsum	Calcium sulfate	CaSO ₄ 2H ₂ O
Street salt	Calcium chloride	CaCl ₂ 2H ₂ O
Muriate of potash	Potassium chloride	KCl
Muriate of sulfate	Potassium sulfate	K ₂ SO ₄

*Assistant Professor and Extension Soil Chemist, Extension Associate; The Texas A&M University System.

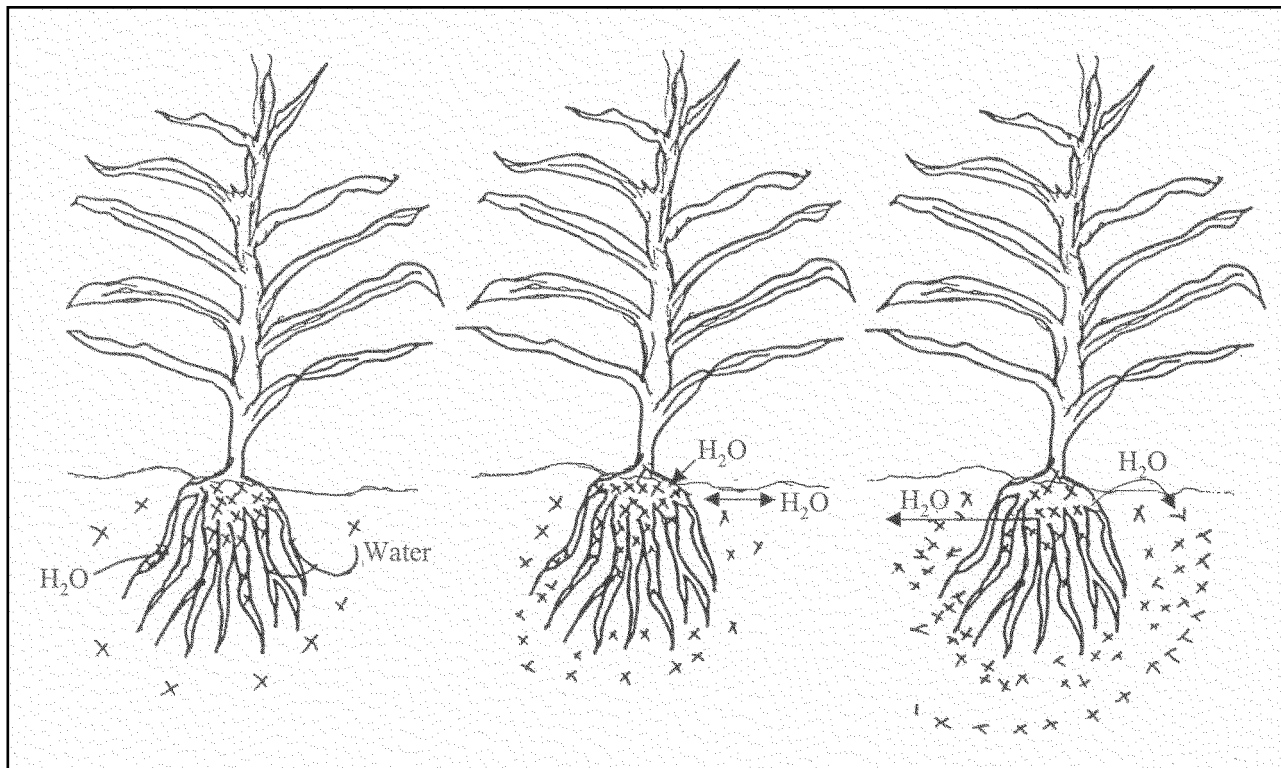


Figure 1. Increased salts in root zone can result in decreased water uptake by plant.

seen. Fortunately, plants take up many salts in the form of nutrients. But when more salt is added to the soil than is removed, the plants will eventually be affected.

In some soils, irrigation and rainwater move through the soil to leach out the salinity. Leaching occurs when water moves materials (such as salts or organic materials) downward through the soil. Several soil factors can inhibit leaching: a high clay content; compaction; a very high sodium content; or a high water table. Salt problems occur when water remains near the surface and evaporates, and when salts are not dissolved and carried below the root zone.

Soils naturally high in soluble salts are usually found in arid or semi-arid regions, where salts often accumulate because there is not enough rainfall to dissolve them and leach them out of the root zone. Salt spray near coastlines can also cause salts to build up in the soil.

In areas with shallow water tables, water containing dissolved salts may move upward into the rooting zone. This occurs by capillary action (similar to the way a wick works), where evaporation serves as the suction of water up through the soil (Fig. 2). Water moves the farthest through finer clay and clay loam soils; it moves less in medium-textured soils (loams); and least in coarser, sandy soils.

Soil testing

To determine the type of problem in your soil, collect a soil sample and have it tested. The best indicator of the extent of a salt problem is a detailed salinity analysis, in which water is extracted from a paste. This test measures the pH, electrical conductivity (EC) and water-soluble levels of the soil. EC is a measure of the amount of dissolved salts in the paste of soil and water.

The Texas Agricultural Extension Service conducts several types of soil tests, including detailed salinity analyses. For more information on soil testing, see Extension publication L-1793, "Testing Your Soil: How to Collect and Send Samples" or check the Web site of the Soil, Water, and Forage Testing Laboratory at <http://soil-testing.tamu.edu>. The laboratory's phone number is (979) 845-4816.

Salt-affected soils

Salt buildup can result in three types of soils: saline, saline-sodic and sodic. Saline soils are the easiest to correct; sodic soils are more difficult. Each type of soil has unique properties that require special management.

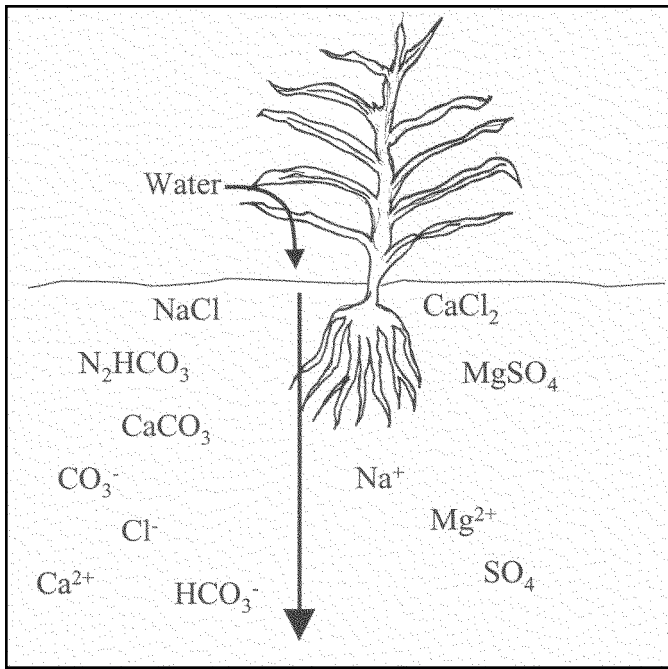


Figure 2. Leaching is the process of adding sufficient water to the soil to dissolve salts and carry them out of the root zone.

- When the salt concentration in the soil is less than that in the plant, water moves from the soil into the plant.
- When the salt concentration in the soil is equal to that of the plant, there is no net movement of water.
- When the salt concentration in the soil is greater than that of the plant, water moves from the plant into the soil.

Saline soils

Saline soils contain enough soluble salts to injure plants. They are characterized by white or light brown crusts on the surface. Saline soils usually have an EC of more than 4 mmho cm^{-1} .

Salts generally found in saline soils include NaCl (table salt), CaCl_2 , gypsum (CaSO_4), magnesium sulfate, potassium chloride and sodium sulfate. The calcium and magnesium salts are at a high enough concentration to offset the negative soil effects of the sodium salts.

The pH of saline soils is generally below 8.5. The normal desired range is 6.0 to 7.0, but many Texas soils are naturally 7.5 to 8.3. Leaching the salts from these soils does not increase the pH of saline soils.

Saline-sodic soils

Saline-sodic soils are like saline soils, except that they have significantly higher concentrations of sodium salts relative to calcium and magnesium salts.

Saline-sodic soils typically have an EC of less than 4 mmho cm^{-1} , and the pH is generally below 8.5. The exchangeable sodium percentage is more than 15 percent of the cation exchange capacity (CEC). CEC is a measure of the soil's capacity to hold cations, namely, calcium, magnesium, potassium, sodium, hydrogen and aluminum. The higher the CEC, the more problematic the removal and remediation of the salt problem.

Water moves through these soils much as it does in saline soils, although the steps for correcting saline-sodic soil are different. Simply leaching the salts from this soil will convert it from saline-sodic to sodic soils.

Sodic soils

Sodic soils are low in soluble salts but relatively high in exchangeable sodium. Sodic soils are unsuitable for many plants because of their high sodium concentration, which may cause plant rooting problems, and because of their high pH, which generally ranges from 8.5 to 12.0.

These high sodium levels disrupt both the chemical and physical composition of soil clays. As a result, the soil surface has low permeability to air, rain and irrigation water. The soil is sticky when wet but forms hard clods and crusts upon drying.

This phenomenon may not occur in very sandy soils because they lack clay content.

Salt problems

When salts accumulate in soils, problems arise for two main reasons: the soil becomes less permeable, and the salt damages or kills the plants.

The first problem is associated with the soil structure. In sodic soils, high levels of exchangeable sodium cause the individual sand, silt and clay particles to be separated and not clumped together into larger particles.

This dispersion makes the soil tight and impervious, so that it allows little air, rain or irrigation water to permeate into the soil. Therefore, the plants may not receive enough moisture and oxygen to grow. Salts may accumulate on the soil surface because they cannot leach out of the root zone.

Plants can also be damaged by salt effects or toxicity. In saline and saline-sodic soils, high concentrations of soluble salts reduce the amount of available water for plants to use. High levels of sodium can be toxic to certain plants.

Also, the very high soil pH in high-salt soils greatly changes the nutrients available to the plants. These high pH levels change the ionic form of many plant nutrients to forms that make them unavailable to plants.

Correcting salt-affected soils

Salt-affected soils can be corrected by:

- Improving drainage
- Leaching
- Reducing evaporation
- Applying chemical treatments
- A combination of these methods

Improving drainage: In soils with poor drainage, deep tillage can be used to break up the soil surface as well as claypans and hardpans, which are layers of clay or other hard soils that restrict the downward flow of water. Tilling helps the water move downward through the soil.

While deep tillage will help temporarily, the parts of the soil not permanently broken up may reseal.

Leaching: Leaching can be used to reduce the salts in soils. You must add enough low-salt water to the soil surface to dissolve the salts and move them below the root zone. The water must be relatively free of salts (1,500 - 2,000 ppm total salts), particularly sodium salts. A water test can determine the level of salts in your water.

Leaching works well on saline soils that have good structure and internal drainage. To leach a highly saline soil, you may need to apply as much as 48 acre-inches of water. An acre-inch is the volume of water that would cover 1 square acre to a depth of 1 inch (27,152 gallons).

Testing is often needed to determine how much water is needed to correct a particular soil. The testing laboratory can advise on how much water to add. After an application, the soil often must be retested to determine whether enough salts were leached out.

Highly saline soils should be leached using several applications, so that the water can drain well. Here again, drainage can be a problem. If the water cannot infiltrate the soil, the salts cannot be dissolved and leached out of the soil.

Reducing evaporation: Applying residue or mulch to the soil can help lower evaporation rates.

Chemical treatments: Before leaching saline-sodic and sodic soils, you must first treat them with chemicals, to reduce the exchangeable sodium content. To remove or exchange with the sodium, add calcium in a soluble form such as gypsum. Again, the laboratory analysis can determine how much calcium to add.

After the calcium treatment, the sodium can then be leached through the soil along with the other soluble salts. Gypsum is the most common amendment used to correct saline-sodic or sodic soils that have no calcium source such as gypsum or free carbonates. These are available at garden centers and agricultural supply stores. Another amendment, calcium chloride, is used in some places, but it is seldom available in most areas.

Many soils in the southern and western two-thirds parts of Texas contain significant concentrations of free limestone, which contains calcium carbonate. Unfortunately, these calcium sources do not dissolve in soils with high pH and therefore cannot help lower sodium levels.

If your soil contains free carbonates, you can add acids to it to form gypsum, which will react with the soil to remove the exchangeable sodium. Add sulfuric acid, sulfur, iron sulfates and aluminum sulfate, which will react in the soil to produce acid. The acid will then react with the calcium carbonates (limestone) to form calcium sulfate (gypsum), water and carbon dioxide. The acidity may also displace some of the sodium.

Table 2 lists typical amendments used to correct salt-affected soils. Although all of these amendments work, to use them you must know the amount of reactive limestone present. In general, gypsum is the safest and most effective material.

Steps for treating sodic and saline-sodic soils

Correcting saline-sodic and sodic soils is a slow process that must be carried out in steps:

1. Treat the surface first, then continue to the lower depths.
2. Apply an amendment to the soil surface and disk it in.
3. Add 10 to 12 inches of water. As when correcting saline soils, you must add enough water to dissolve as well as maintain the calcium concentrations in solution and to move the salts and sodium through the soil.

Table 2. Typical soil amendments for correcting saline and saline-sodic soils¹

Amendment	Chemical Formula	Purity, %²	Approximate No. Pounds to Supply 1,000 Pounds of Soluble Calcium³
Gypsum	CaSO ₄ 2H ₂ O	100	4,300
Calcium chloride	CaCl ₂ 2H ₂ O	100	3,700
Sulfur ⁴	S	100	800
Sulfuric acid ⁴	H ₂ SO ₄	95	2,600
Iron sulfate ⁴	FeSO ₄ 7H ₂ O	100	6,950
Aluminum sulfate ⁴	Al(SO ₄) ₃ 18H ₂ O	100	5,550
Lime-sulfur solution ^{4,5}	Calcium polysulfide	24	3,350

¹ From USDA Agriculture Information Bulletin No. 195. (1)

² With purities less than these, additional material will need to be supplied.

³ Assumes free carbonates present to react with the amendments that contain no calcium.

⁴ Sulfur amendments are only used in soils that contain free calcium carbonates.

⁵ Expressed as sulfur content.

However, do not add so much water that it remains ponded on the soil surface for extended periods.

Generally, this process must be repeated over time. A good goal is to remove the sodium to a minimum depth of 3 to 4 feet.

Test the soil periodically to pinpoint potential salinity problems and to measure your progress in correcting salt-affected soils.

The amount of amendment you need to correct saline-sodic and sodic soils is based on the amount of sodium in the soil. Several other factors also influence the amount applied: the leaching rate, the solubility and reaction rates of the amendments, and the conversion of free carbonates to gypsum.

If you take steps early, correcting the soil will be easier and less expensive, and it will have less negative impact on soils and plants.

Produced by AgriLife Communications and Marketing, The Texas A&M University System
Texas AgriLife Extension publications can be found on the Web at: <http://AgriLifebookstore.org>

Educational programs of the Texas AgriLife Extension Service are open to all people without regard to race, color, sex, disability, religion, age, or national origin.

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Chester P. Fehlis, Deputy Director, Texas Agricultural Extension Service, The Texas A&M University System.