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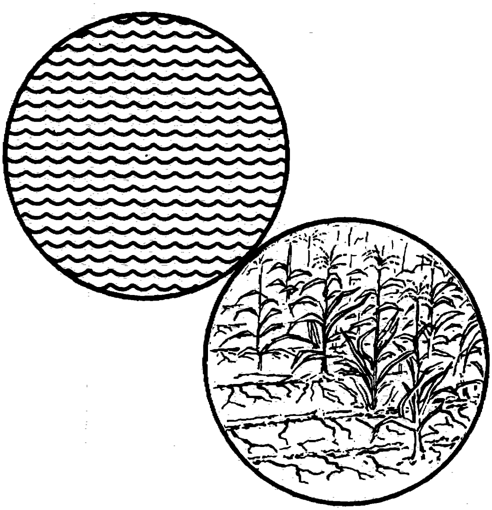
# AVAILABILITY of WATER to CROPS on SALINE SOILS



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UNITED STATES DEPARTMENT OF AGRICULTURE

# SOIL SALINITY—

*Restricts water intake by plants*
*Delays germination*
*Limits seedling survival*
*Stunts growth*

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# AVAILABILITY of WATER to CROPS on SALINE SOIL

By **L. A. Richards,** *physicist, United States Salinity Laboratory, Soil and Water Conservation Research Division, Agricultural Research Service*

The weight of growing crops is composed mostly of water. Flow of water into the roots and out through the leaves is normal for most crops in carrying on growth processes. If water in the plant becomes deficient, either by excessive evaporation or by limited availability in the soil, the rate at which the plant can grow is decreased.

Many factors control growth, such as nutritional elements in the soil and physical conditions in the whole plant environment, but water status within the plant is always a major factor and is often limiting. Soil salinity directly affects the availability of water to plants.

## SUCTION CONDITION OF SOIL WATER

The availability of water to plants is influenced by two force actions.

Water is pulled into soil pores just like ink is pulled into a blotter. The bony framework, or matrix, of the soil is made up of solid mineral particles. Water is strongly attracted to and is held on the surface of the soil matrix. This holding action of soil for water is measured in terms of the suction required to get water back out of the soil and is referred to as *matric suction.*[1]

[1] "Soil suction" and "soil-moisture tension" are terms that are sometimes used and mean the same thing as matric suction.



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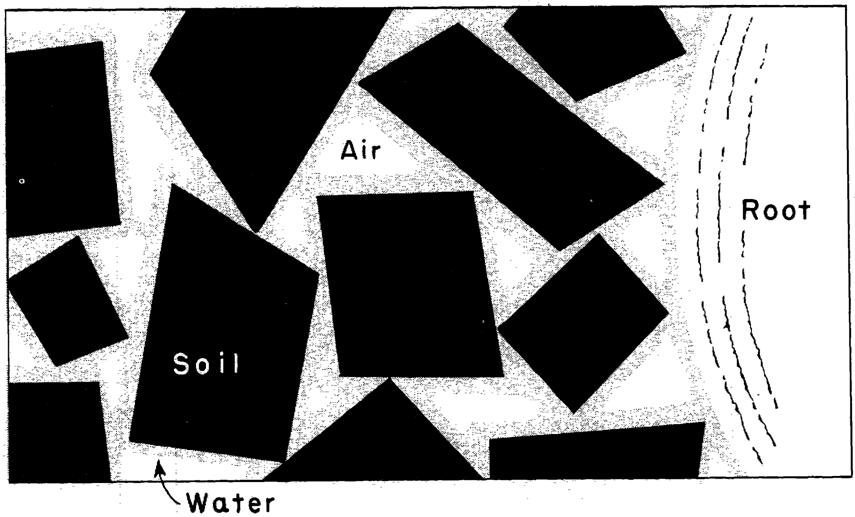


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**Molecular attraction holds water on the soil surface. To get water, the plant must overcome this holding action, or suction effect, of the soil matrix.**

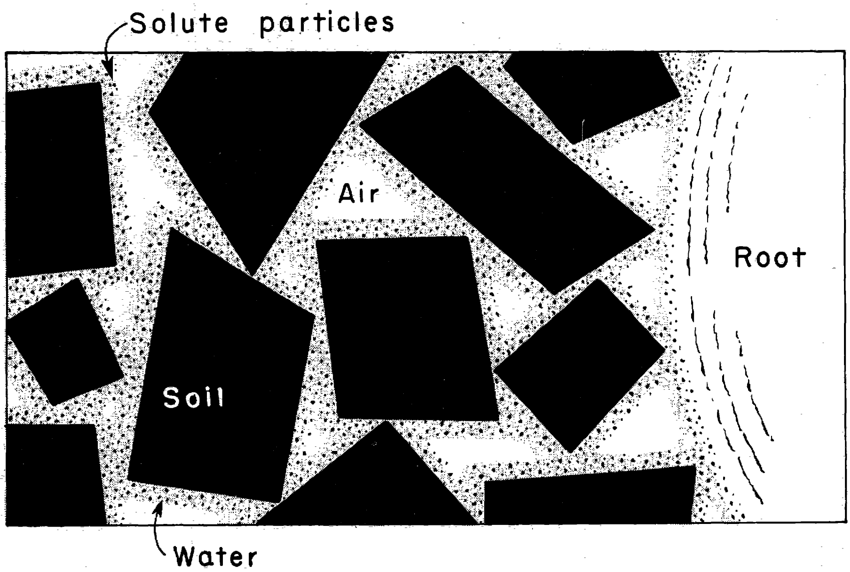
When soil is saturated with water, the solid and the liquid occupy about equal parts of the bulk volume. As the soil dries out, the bulk volume does not change much, but part of the water is replaced by air.

Another holding action for water in soil comes from dissolved salt. Dissolved salt particles, or solute particles as they are called, are always present in the soil solution. They have attraction for water and oppose the absorption of water by plant roots. This osmotic action is referred to as *solute suction.*

The intensity of these two force actions determines the suction that must be overcome before plant roots can take in water. The *total suction* of soil water is the sum of *matric suction* and *solute suction.*

## MATRIC SUCTION DEPENDS ON THE AMOUNT OF WATER IN SOIL

Soil is composed of many fine particles and presents an extensive wetting surface. One pound of sandy soil may have 3 acres of surface area, while a pound of clay soil can have as much as 25 acres of surface area. Soil can contain a relatively large amount of water, and yet all the water will lie in a thin film that is held tightly on the surface of the soil particles. Matric suction is a measure of the tenacity with which water is held on the soil surface and depends on the thickness of the water film. As water is removed from soil, the films become thinner and greater suction is required for plant roots to remove water from the soil.

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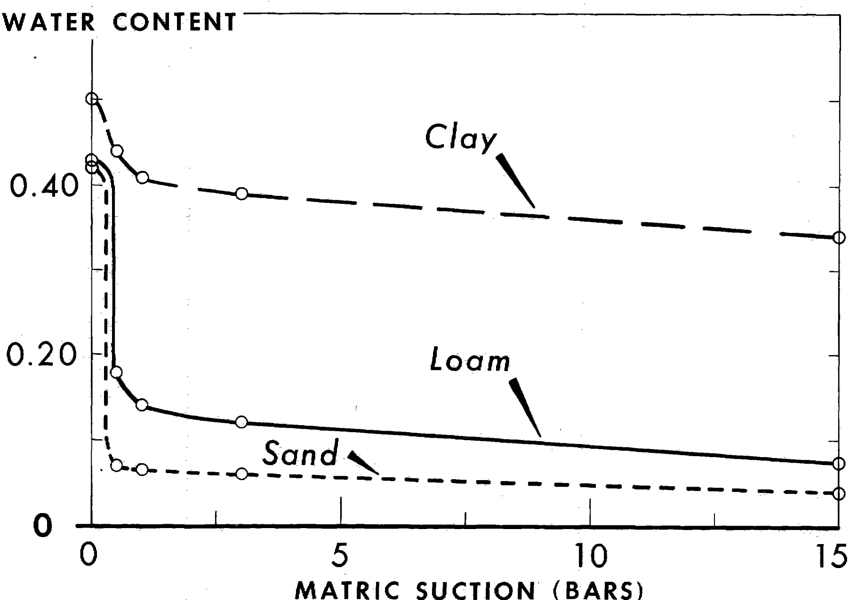
**Solute particles also exert a holding action on water. To get water from the soil solution, plants must overcome solute suction as well as matric suction.**

Matric suction is negligible in saturated soil but increases continuously as the soil dries. A day or two after thorough irrigation, the matric suction in a well-drained soil is usually in the range of

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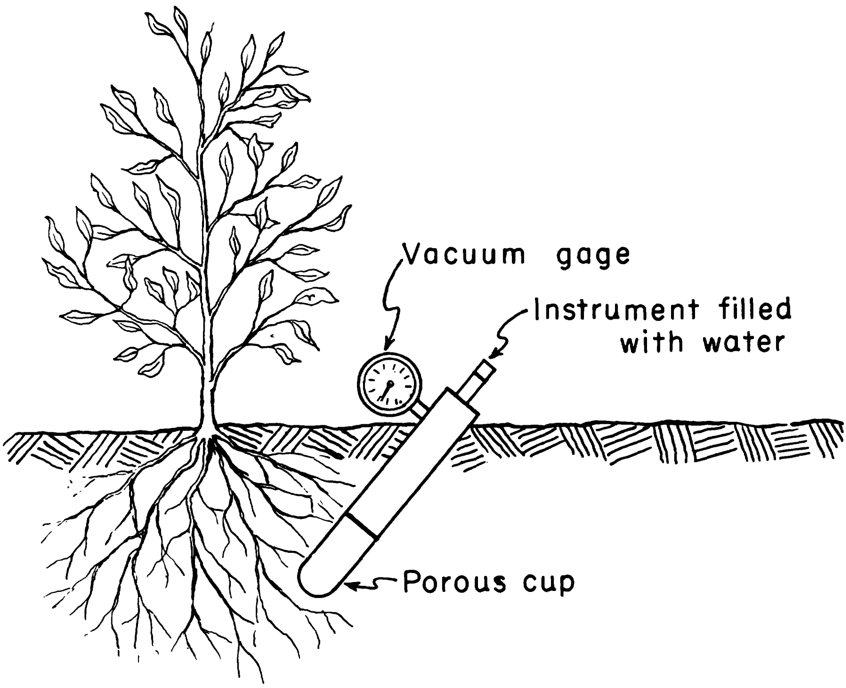
**Water-retention curves for fine (clay), medium (loam), and coarse (sandy) soils. Water-content scale represents fraction of bulk soil volume occupied by water.**

5 to 15 centibars.[2] When a nonsaline soil becomes dry enough to cause crops to wilt, the matric suction may be in the range of 10 to 20 bars.

The soil moisture tensiometer is an instrument that can be used to measure matric suction up to about 85 centibars. It consists of a vacuum gage connected to a porous cup that is buried in the soil. The instrument is kept full of water during use. Soil moisture tensiometers have long been used in agricultural research. They are now commercially available and are widely used by farmers to tell when to irrigate.

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**The tensiometer is an instrument for measuring matric suction.**

Tensiometers cover only about one tenth of the matric suction range in which plants grow well, but when properly placed in the root zone they cover the range that is economically important for most irrigated crops. Higher values of matric suction can be measured with instruments that depend on electrical and thermal conductance.

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[2] The bar is a metric unit of pressure. It corresponds to 75 cm. of mercury, or 14.5 pounds per square inch. The reading of a barometer at sea level is approximately 1 bar. One bar is equal to 100 centibars.

## SOLUTE SUCTION DEPENDS ON SALT CONCENTRATION IN THE SOIL SOLUTION

Root membranes in contact with the soil solution absorb the water more readily than the salt. Water molecules pass through the membranes, but the salt is mostly screened out and left behind in the soil. Extra suction is required in the root to separate water from the additional binding action that occurs when soils contain soluble salts. Water entry into roots is restricted by the solute suction of the soil solution.

Solute suction depends not alone on the amount of salt in the soil but also on the amount of water in the soil at the same time. For example, on a dry-weight basis, a sandy soil may have a water content of 8 percent a day or two following irrigation. This may be reduced to 4 percent by root extraction. On the other hand, a fine-textured soil may have a water content of 40 percent a few days following irrigation, and this may later be reduced to 20 percent by root action. Thus, for the field-moisture range, the fine-textured soil could contain 5 times as much water as the sandy soil.

This means that fine soil could have five times as much salt on a dry-weight basis as a sandy soil and yet would have the same concentration of salt in the soil solution and would have the same solute suction.

## RELATION OF SUCTION TO PLANT GROWTH

Solute suction plus matric suction give the total suction that acts against the entry of water into plant roots. When other growth factors are favorable, the rate of growth of crop plants decreases as the total suction of soil water increases.

In nonsaline soils, most crops show visible wilting symptoms and vegetative growth ceases when matric suction gets as high as 10 bars in a major part of the root zone. Studies with saline soils indicate that total suction is initially higher and increases less rapidly with time after irrigation. Wilting symptoms may not become apparent, but growth and yield are depressed.

Crops differ markedly in their capacity to overcome suction and make acceptable growth. Crops that can obtain water and grow successfully when the matric suction is high are called drought-tolerant. Crops that can adjust to high solute suction are called salt-tolerant. Lists are available from the U.S. Department of Agriculture in which various crops are arranged in the order of their salt tolerance.[3]

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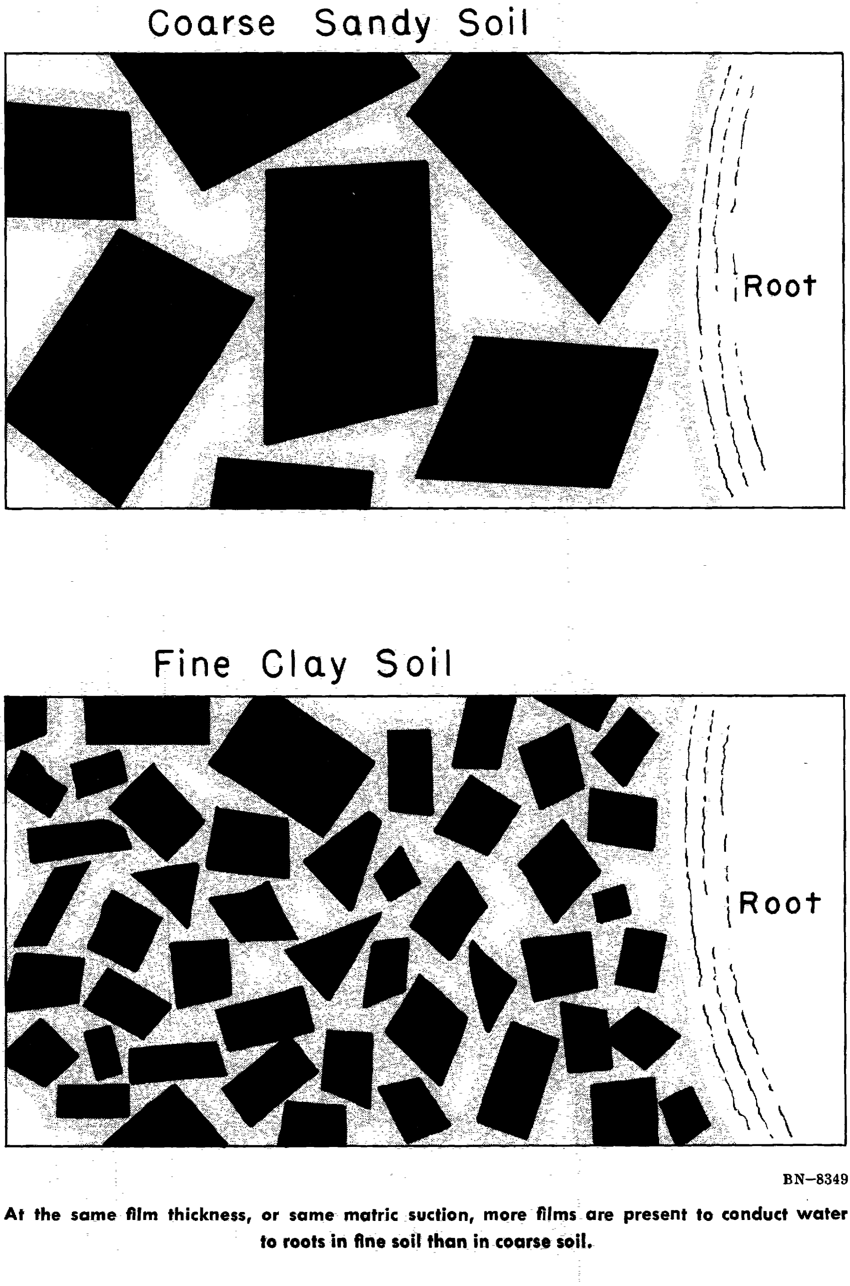
[3] BERNSTEIN, LEON. SALT TOLERANCE OF GRASSES AND FORAGE LEGUMES. U.S. Dept. Agr. Agr. Inform. Bul. 194, 7 pp., illus. 1958.

BERNSTEIN, LEON. SALT TOLERANCE OF VEGETABLE CROPS. U.S. Dept. Agr. Agr. Inform. Bul. 205, 4 pp., illus. 1959.

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**At the same film thickness, or same matric suction, more films are present to conduct water to roots in fine soil than in coarse soil.**

## WATER AVAILABILITY TO PLANTS DEPENDS ALSO ON WATER FLOW IN SOIL

Plant roots actually contact only a small fraction of the soil particles. Supply of water to the plant, therefore, depends not only on the condition of water in the soil layer next to the root but also on the movement of water through the soil to replace the water that has passed into the root.

Water flow in moist soil takes place in the water films surrounding the soil particles. Clay soils have many more particles per unit volume, more surface, and, therefore, more films for transmitting water than sandy soils.

Sandy soils are easier to manage in some ways than clay soils, but crops grown in sandy soils are more likely to develop drought symptoms. This is because sandy soils contain a smaller area of the water films which both store and transmit water for plant use.

The texture of soil refers to particle-size distribution, and this is one factor that soil management must take into account. Good crops can be raised on soils representing a wide textural range from coarse sands to fine clays if soil properties, including those affecting the availability of soil water, are properly taken into account.

BN–8345–X

**Example of good soil-water management for cotton on a fine-textured soil using high-salinity irrigation water. Even spreading of the water without flooding or erosion is required.**

## TOXIC EFFECTS OF SALINITY

A soil that contains enough soluble salt to interfere with the growth of most crop plants is called a saline soil.

Water availability is always a factor in saline soils, but in addition there may be specific toxic effects of certain salts on certain crops.

Toxicity effects of salinity are more complicated to diagnose, but fortunately the treatment is the same as for solute-suction effects. In either case, more water must be applied at the soil surface than the soil in the root zone can hold. The excess water drains away, carrying the soluble salt with it.

## OCCURRENCE OF SALINITY

Salinity is a special problem to farmers who practice irrigation, because all irrigation waters contain salts. Saline soils usually occur in arid climates. Soils become saline by having dissolved salts carried into them by water. This occurs by natural flooding, irrigation, or the upward movement of water into the root zone from a shallow ground-water table. Fertilizers contain salt and, in some kinds of intensive agriculture, this source of salinity must be taken into account. Water lost from soil by evaporation, either from the soil surface or from plant leaves, does not remove salt. The only effective means for removal of salt from soil is by downward movement in solution and outflow in the drainage water.

BN–8346–X

**Grapevine defoliated by sudden rise of saline ground water during the irrigation season. The berries will soon wither and die. Adequate drainage is a requirement for successful irrigation.**

Greenhouse soils must be given special attention because the glass cover prevents leaching by rain. As a result, growth depression from accumulated salt often occurs.

## RELATION OF IRRIGATION TO SALINITY

In general, if soil contains much salt, solute suction will be high. To obtain good plant growth, saline soil must be kept at a high moisture content because this reduces both matric suction and solute suction.

In effect, the presence of soluble salt limits the amount of water that can be extracted from the soil root zone by the crop before irrigation is again needed to maintain good growth.

Another reason for applying more water to a saline soil than to a nonsaline soil is that soil salts can be effectively removed only by leaching. For this, enough water must enter the surface to produce downward percolation and outflow of drainage water from the root zone.

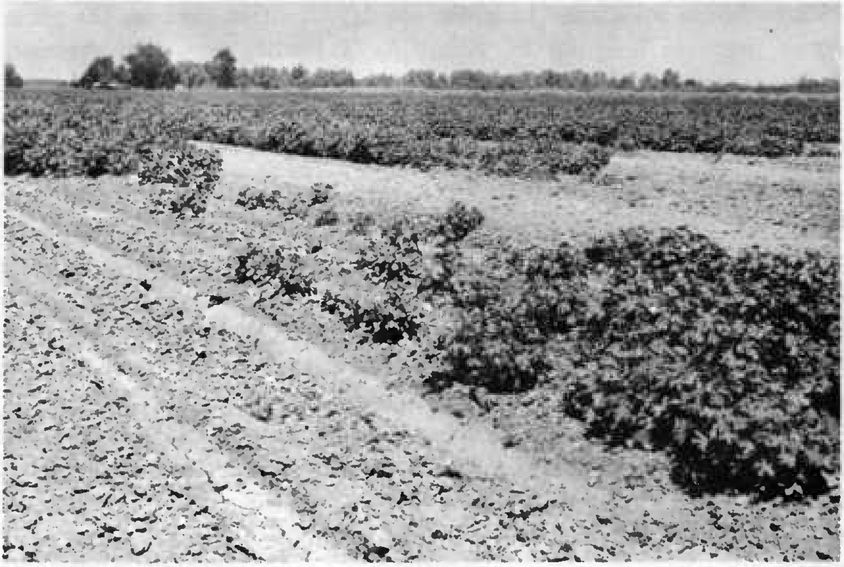
## DETECTION OF SOIL SALINITY

Unfortunately, visual symptoms of salinity are not reliable. A white crust may form on the surface of saline soils, but this does not always occur. When gypsum is present a white crust usually forms, but this salt contributes little to salinity because of its limited solubility.

Calcium chloride has a strong attraction for water, and when present in the soil surface it may cause the surface to remain moist and appear dark. If the salt in the soil is composed predominantly of sodium, sometimes a black evaporation deposit will form at the soil surface. This usually indicates that the soil has an alkaline reaction, causing the organic matter of the soil to become soluble and to accumulate as a dark deposit at the surface as the result of evaporation. Salt-affected soils containing mainly sodium salts are referred to as sodic soils and represent a special class of problem soils.

Plants sometimes do not show visible symptoms of soil salinity. Typical leaf burns may appear on some plants with certain salts, but the main effects of salinity are the impairment of germination and seedling survival and the slowing up of growth or stunting of plants. This checking of growth may be accompanied by a dark-green or bluish appearance of the plant, somewhat similar to the color that occurs under drought conditions.

The best way to detect soil salinity is to test the soil. Salinity tests are inexpensive.



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**Plant condition will often indicate salt spots in a field. When salinity is uniform, yield losses often go undetected.**

## TESTS FOR SOIL SALINITY

Electrical conductivity is related to the solute suction of soil solutions and, since it is easy to measure, it is used for appraising soil salinity. To compare the salinity of different soils, it is necessary to make the measurement at a moisture content that is related to the field-moisture range.

A saturated soil paste is satisfactory for this purpose and is prepared by stirring a sample of the soil while adding distilled water. The mixing vessel should be tapped on the workbench from time to time during the wetting process. The saturation point is reached when the paste glistens and will slide freely off the spoon or spatula.

It is a relatively simple operation to extract a sample of the solution from a saturated soil paste and to measure the electrical conductivity. Portable sets for measuring salinity by this method have been designed by the U.S. Department of Agriculture and are available commercially. Procedures for tests are given in another publication of the Department.[4] Farm advisers, Soil Conservation Service field men, and soil testing laboratories are often equipped to make salinity measurements.

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[4] Richard, L. A., Bower, C. A., and Fireman, Milton. TESTS FOR SALINITY AND SODIUM STATUS OF SOIL AND OF IRRIGATION WATER. U.S. Dept. Agr. Cir. 982, 19 pp., illus. 1956.



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