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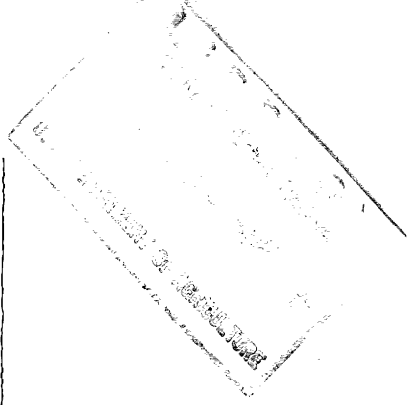
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***Salt
Problems
in Irrigated
Soils***

*Agriculture Information
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UNITED STATES DEPARTMENT OF AGRICULTURE

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Prepared by the staff of the U. S. Salinity Laboratory (Riverside, Calif.), Soil and Water Conservation Research Division, Agricultural Research Service

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Salt Problems

in Irrigated Soils

More than one-fourth of the irrigated farmland in the United States does not produce abundantly because the soil is salt-affected.

Salt-affected soil may contain too much salt, too much sodium, or both. An accumulation of salt in the soil may retard plant growth. When sodium, which is contained in common salts, is adsorbed on

(adheres to) soil particles, the soil may be difficult to till, and water penetration may be poor.

Salt problems are especially serious in 17 Western States, where more than 7 million acres of irrigated land is salt-affected. A similar condition exists in a less extensive acreage of nonirrigated crop and pasture land.

ORIGIN AND CAUSES OF SALT BUILDUP

Where Does the Salt Come From?

Salt comes from the minerals of the earth's crust. Weathering decomposes the minerals and releases the salt in a soluble form.

Humid regions usually have enough rainfall to leach this salt through the soil and into the ground water, which carries it to streams. The streams carry it to the oceans.

In arid regions rainfall is too scanty to leach the salt out of the soil. The rain is largely dissipated by evaporation and by plant use. Both processes—evaporation and plant use—occur at higher rates in arid regions than they do in humid regions.

Scanty rainfall, evaporation, and plant use favor salt buildup in arid regions. A salt buildup caused by these conditions alone, however, is usually not extensive enough to cause trouble. A harmful buildup, or accumulation, occurs when a field continually receives salt from

other locations. The salt is brought into the area by surface water or by ground water. Irrigation often speeds the process.

Why Does Salt Accumulate in Soil?

Salt accumulates when water evaporates at the surface, or is extracted by plant roots. Both processes separate the salt from the water. The salt remains behind. Salt is removed from the soil when water moves downward through the root zone and into the subsoil, or out into the ground-water drainage system.

The rapidity with which salt builds up in the root zone is determined by the quality of the irrigation water, the method of irrigation, the type of field drainage, and other conditions.

Quality of Irrigation Water

All irrigation waters contain dissolved salt. The salt content varies

from 0.1 of a ton to 5 tons or more per acre-foot. Since 5 or more acre-feet of irrigation water may be applied in a single season, it is possible for an acre of irrigated land to receive as much as 25 tons of salt in 1 season.

It is extremely important that irrigation water be tested to determine its quality. A water-quality test may alert the farmer to two hazards—the presence of salinity or the possibility of the formation of a sodium soil. It also can reveal the presence of excessive amounts of bicarbonate, or boron, or both. Bicarbonate is harmful if the amount contained in irrigation water is high in relation to calcium and magnesium. Although boron in small quantities is essential to plant growth, it is toxic to many plants at concentrations only slightly above those needed for normal growth.

Method of Irrigation

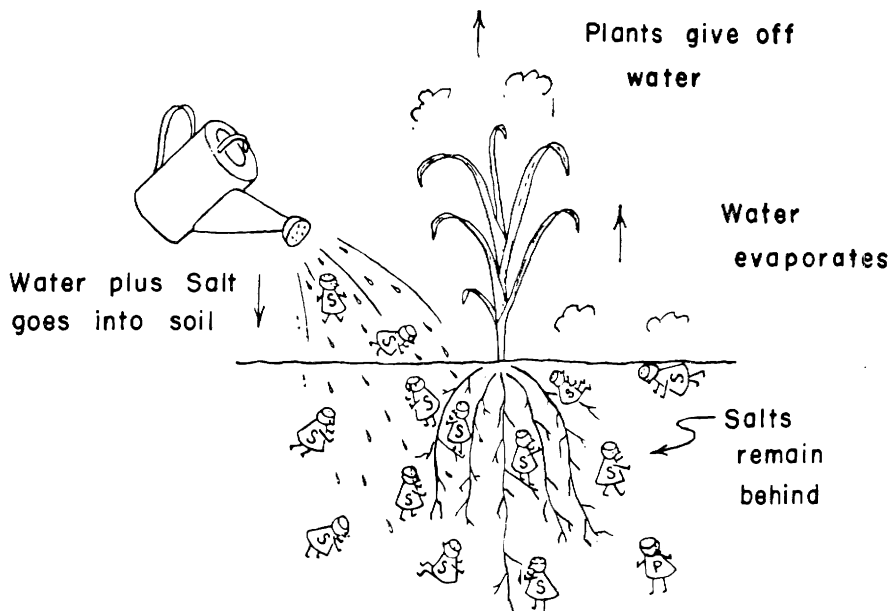
Water is usually in plentiful supply when an irrigation project begins. Consequently, too much water is applied. This excess water often does more harm than good, because it tends to raise the water table and thus increases drainage problems.

Too little water prevents the natural leaching process by which the salts are carried beyond the root zone of the plant.

The proper amount of irrigation water applied to a field should be sufficient to replenish losses by plant transpiration and evaporation, and to leach out the salt that has accumulated during previous irrigations.

Type of Drainage

Adequate drainage is important in maintaining a low salinity level.



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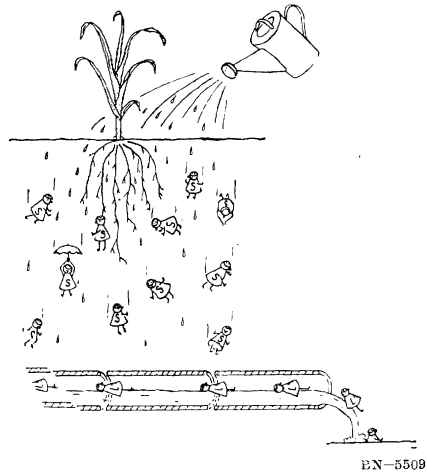
All irrigation waters contain salts. Salts build up in the soil when the amount of water applied is only enough to meet crop needs.

If a field is not adequately drained, water may accumulate in the root zone and saturate the soil. This hastens the rise of the water table. When the water table rises to within 5 or 6 feet of the surface, ground water and its salt move upward into the root zone and to the soil surface. The reason for this condition is that the ground water tends to move upward to the drier soil. Ground water, therefore, contributes to the salinity condition of the soil.

Adequate drainage keeps the water table from rising and allows the water to flow away before it has a chance to rise into the soil zone occupied by the roots of the crop.

Other Conditions

Some fields accumulate salt because of their location, because they are not level, or because the soil is impermeable. Low valleys located close to streams are usually irrigated first because the water is readily accessible. As irrigation is expanded, fields progressively higher on the valley slope are also irrigated. This process continues until a step-like arrangement of fields exists. Irrigation water applied to the highest field drains into the ground water of the fields below it. The lowest field, therefore, receives



Where natural drainage is not adequate, tiles or open drains assist in removing salts from the root zone.

all the drainings and may become hopelessly polluted by salt.

A field that is not level has a tendency to accumulate salt. High spots seldom receive enough water. Too little water favors salt buildup.

Soils differ in their permeability—that is, their ability to take water. The least permeable are usually the most vulnerable to salt accumulations because water cannot move through them readily. Cementlike formations underlie some soils and aggravate the problems of drainage.

EFFECT ON PLANTS AND SOILS

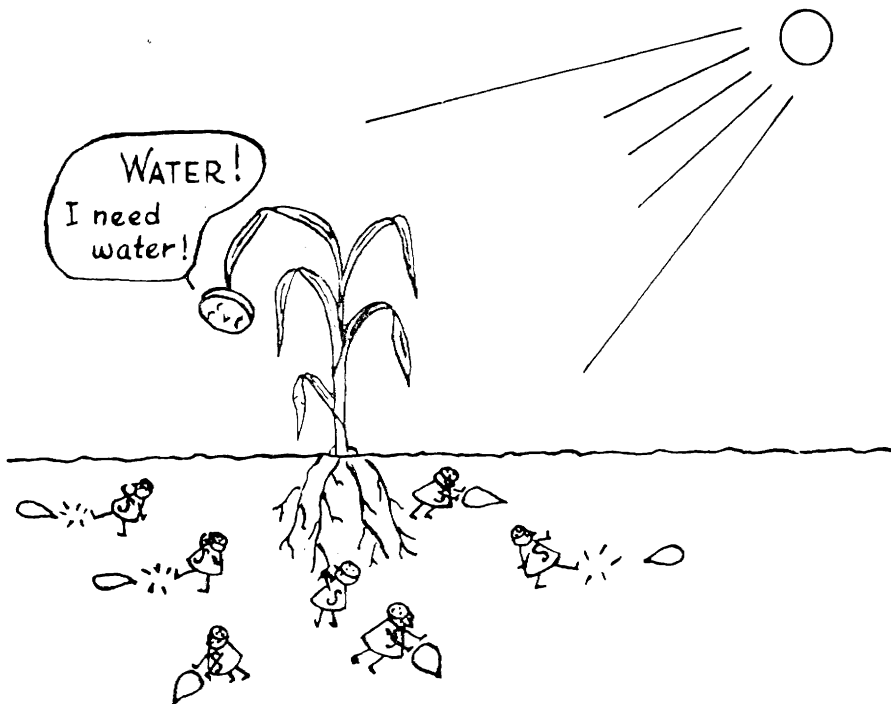
How Does Too Much Salt Affect Plants?

Too much salt in soil affects plants in two ways:

1. It prevents them from getting enough water, even though the soil may be well watered. This results in stunted plants that frequently have a characteristic blue-green color. If the salt is evenly distributed in a field, all the plants will

be stunted. Yields may be reduced as much as 25 percent.

2. It has a direct toxic effect on plants. Most fruit trees are susceptible to injury from salt toxicity. A characteristic leaf-burn develops; leaves fall off. Trees may die when harmful amounts of sodium or chloride accumulate. Most field, forage, and truck crops, however, may accumulate larger amounts of sodium or chloride in



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The presence of salts in the soil makes it difficult for crops to take up water.

the leaves without developing visible symptoms of toxicity injury. Boron and bicarbonate are toxic to all species of plants, but the level of tolerance may vary from one crop to another.

How Does Too Much Salt Affect Soil?

Salt-affected soils are soils that have been harmed by soluble salts. They are classified into three different groups—saline soils, sodic soils, and saline-sodic soils.

Saline Soils

Soils that contain too much soluble salt are called saline soils. These soils are generally flocculated—that is, the soil particles are grouped together in clumps. The clumps are crumbly and do not stick together; water and air move

freely between them. Although this condition improves soil structure, the soluble salt reduces the rate at which plants absorb water. Consequently, plant growth is retarded.

Sodic Soils

Soils that have appreciable amounts of sodium adsorbed on (adhered to) their individual particles are called sodic soils. They are not flocculated because the soil particles on which the sodium is adsorbed separate from the flocculated clumps. This separation causes the openings between the clumps to become smaller. Water and air cannot move through the soil freely, even though there may be more openings. In some localities, the soil becomes a swollen, gelatinous mass that is impervious to both air and water. This adverse

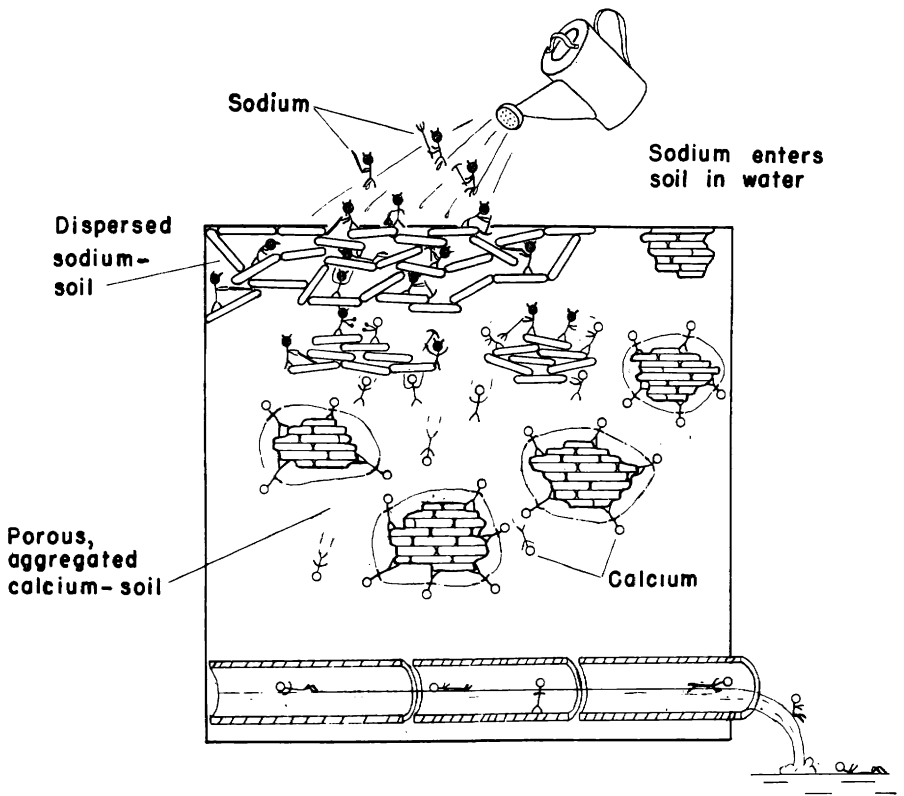
effect of sodium becomes worse when soluble salts are low.

Dry sodic soils are hard. The dispersed soil particles stick together and form a crust that retards or prevents seedling emergence. The soil breaks up into hard clods when tilled.

Sodium is also toxic to certain plants. Visible toxicity signs, however, usually do not appear until the sodium concentration has reached a point where it is sufficient to impair the soil physically, although trees and some other plants are sensitive to lower concentrations.

Sodic soils are formed by a chemical process. Sodium, actually a salt constituent, exists in solution as a "cation." Cations are very small positively charged particles. Soil particles, which carry negative charges, attract the positively charged sodium cations. As a result, sodium cations are adsorbed on soil particles.

Other cations, or positively charged particles, that adhere to soil particles are calcium and magnesium. Calcium and magnesium are the dominant cations in most productive soils in arid regions.



BN-5507

When irrigation water containing a high proportion of sodium is applied to porous, aggregated soil on which calcium is adsorbed, the sodium replaces the adsorbed calcium and causes the soil particles to rearrange so as to form small pores through which water moves slowly. This process is reversed when soluble calcium is applied to the soil and structure-building practices are employed.

When productive soils are irrigated with high-sodium irrigation waters, sodium replaces a part of the calcium and magnesium. This reaction is called cation exchange. It is a reversible process. The capacity of the soil to adsorb and exchange cations is limited. The percentage of this capacity that sodium takes up is called the exchangeable-sodium-percentage. Soils that are harmed by adsorbed sodium usually have an exchangeable-sodium-percentage of 15 or more.

Saline-Sodic Soils

Saline-sodic soils occur when salinity and adsorbed sodium affect the soil at the same time.

How Can Saline Soils Be Recognized?

Crop growth on saline soils is usually poor and spotty because the salt delays or prevents seed germination. If seeds do sprout, the young plants may soon die. Irregular bare patches then appear in the field. The poor, spotty stands and the irregular bare spots are usually surrounded by areas of uneven growth.

Another sign of saline soil is the appearance of a white crust on the surface of the soil. This sign, however, may not be a true indication of salinity because nonsaline soils that contain gypsum also have white crusts.

It is not always possible to tell by visual inspection when a field contains too much salt. A better plan is to analyze suspected soils. It is cheaper to pay for a test than to wait until visible signs appear. When visible signs do appear, it is usually too late to save the crop.

How Can Sodic Soils Be Recognized?

Sodic soils often exhibit black surface deposits. Such a soil is sometimes referred to as "black alkali." The black deposits occur because the sodium dissolves the organic matter in the soil. Small, irregular areas of sodic soil are called "slick spots."

Sodic soils usually take water slowly. This fact, however, is not an infallible indication. Other kinds of soil—clay soil, soils that have a plow sole, and those cultivated when they are wet—also take water slowly.

IMPROVING SALT-AFFECTED SOILS

How May Saline Soils Be Improved?

Saline soils may be improved by leaching.

Leaching is the process in which extra water is added to a field and allowed to soak through the soil and drain away underground. A common method of leaching is to pond the water in basins over the entire field. Leaching is not effective if the ground-water table is too close to the surface. If natural drainage cannot take care of the additional water, artificial drains

should be installed. Sometimes the excess water is removed by pumping from wells. Permissible depths for ground-water tables vary according to the type of soil being irrigated.

The amount of leaching water that enters the soil by surface flooding determines how much salt is removed from the soil. When water is leached through the soil, a surface depth of 6 inches of water for every foot of plant root zone will leach out 50 percent of the salt. One foot of water for every foot



BN-5502

Poor, spotty stand is a sign of soil salinity in this California bean field.



BN-5501

Bare spots and uneven growth indicate salinity in this barley plot near El Centro, Calif.

of root zone leaches out 80 percent of the salt. Two feet of water per foot of root zone leaches out 90 percent of the salt. If leach water is added to a field by methods other than ponding, more water will be required to accomplish the same results.

The upward movements of saline water from shallow water tables can cause salt buildup in the plant root zone. A water table should be at least 4½ to 5 feet below the surface during most of the crop growing season. Frequent water-table measurement in an open hole at several locations in a field will indicate whether drainage is adequate.

Careful leveling of the land makes possible a more uniform application of water and better salinity control. High spots in an uneven field may not receive enough water for good crop growth or for leaching purposes.

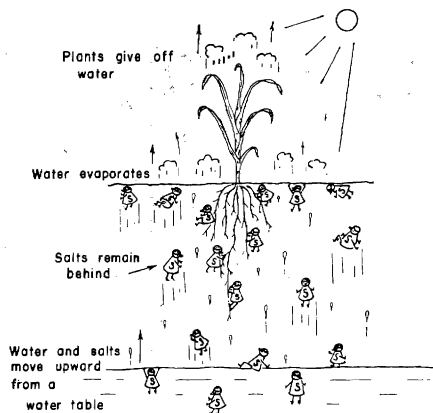
How May Sodic Soils Be Improved?

Sodic soils may be improved by adding chemical amendments, leaching the soil, and then employing practices that build soil structure.

Adding Chemical Amendments

Most sodic soils need chemical amendments to restore their productivity. Many suitable amendments are available; gypsum and sulfur are the most common. Since most amendments are expensive, it is always wise to have the soil tested to determine the kind and amounts needed.

It is not always necessary to supply amendments to improve sodic soils. Some sodic soils, for example, contain calcium sulfate (gypsum), and when they are leached the water dissolves the gypsum and frees the calcium. This dissolved



BN-5506

Salts build up in the soil from shallow water tables.

calcium replaces the adsorbed sodium. The sodium salts formed from this reaction can be removed by leaching.

Some irrigation water contains appreciable amounts of calcium or magnesium. When such water is applied to sodic soil, an exchange reaction takes place. The sodium is replaced and removed from the soil.

Leaching the Soil

Sodic soils should be leached after an amendment is applied. This process is necessary to remove the sodium from the soil. For most amendments, the soil can be leached immediately after the amendment is applied. However, if sulfur is used, it is better to wait 2 or 3 months before leaching the soil. This waiting period is needed to allow the necessary chemical reaction to take place. Reactions occur more readily when the soil is moist.

Improving Soil Structure

Subsoiling or deep plowing sometimes helps to restore the structure of sodic soil. These prac-

tices alone, however, have little value unless an amendment is applied.

Applying manure or other organic matter to the soil will also help to improve soil structure.

How May Saline-Sodic Soils Be Improved?

Saline-sodic soils may be improved in the same manner outlined for sodic soils. Usually it is best to apply amendments before leaching. If leaching is done first, the permeability of the soil declines markedly and the rate of reclamation is retarded.

How Much Improvement Is Feasible?

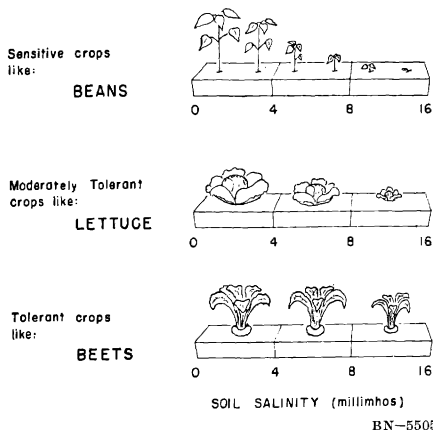
Complete reclamation of salt-affected soils is not always economically feasible. One or more of the following factors may be involved:

1. The high cost of chemical amendments.
2. Low permeability of the soil.
3. Inadequate drainage.
4. The unavoidable use of poor-quality irrigation water.

If the soil cannot be reclaimed completely, suitable management practices may be helpful in maintaining production.

Crop Selection

Crops vary widely in their tolerance to salts. Sugar beets, cotton, and barley can tolerate up to 10 times as much salt as most clover, beans, and fruit trees. For most moderately tolerant and sensitive crops, there is no "safe limit" of salinity. Even at low levels of salinity, there may be some stunting of plants and a reduction in yield without visible symptoms of injury. As the soil becomes saltier, stunting becomes more pronounced and yields become lower.



Crops vary widely in their tolerance to salt.

The buildup of exchangeable sodium on soil particles has an adverse effect on many crop plants. Tree crops that show specific sodium toxicity include almonds, apricots, avocados, citrus, and plums. Crops such as beets, barley, and tall wheatgrass are relatively sodium tolerant.

Soil specialists from the Agricultural Extension Service and the Soil Conservation Service can supply lists showing the relative salt and sodium tolerance of crop plants.

Tillage Methods

Salt-affected soils require special tillage methods to help control salinity and sodium. These soils should not be tilled when moist. Heavy machinery should not be moved over them. More frequent irrigation, especially during the germination and seedling stages of plants, tends to soften the crust on sodic soils and helps in producing a better stand.

Modifying the method of irrigation and the shape of the seedbed may alter considerably the tendency of salt to accumulate near the seed. For example, pre-emergence irrigation in special furrows placed

close to the seed reduces the soluble salt concentration around the seed and permits germination. After seedlings are established, the special furrows may be abandoned and new ones made between the rows.

Irrigation Methods

The main methods of applying water are flooding, furrow irrigation, sprinkling, and subirrigation.

Flooding provides better salinity control if the land is sufficiently level and if the crop is a type that can be flooded.

Furrow irrigation is well adapted to row crops, especially if the land is too steep for flooding. Although this method allows salts to accumulate in the rows, plowing and mixing the entire soil surface periodically prevents serious increases in the salt content of the soil.

If salts accumulate in the soil during the growing season, they can sometimes be removed by off-season leaching.

Irrigation by sprinkling allows a close control of the amount and distribution of water. Growers

can apply too little water by this method, and, as a result, complete leaching of salts beyond the root zone does not occur.

Subirrigation is not suitable when salinity is a problem.

The moisture content of saline soils should be maintained as high as practicable, especially during the stage of vegetative growth.

The amount of water applied should be sufficient to supply the crop needs and satisfy the leaching requirement, but not enough to overload the drainage system. If the capacity of the system is exceeded, the water table will rise to an unsafe level. Maintaining a drainage system is also important. This means keeping tile lines in repair, keeping open ditches clean, and excavating to grade.

Other Practices

Good management practices also include the adoption of special treatments such as adding soil amendments, supplying organic matter, and the growing of sod crops to maintain soil structure.

WATER AND SOIL ANALYSES

Chemical analyses of the available irrigation water and the suspected soils are recommended. A water-quality analysis should include tests for the total amount of salts in solution, calcium plus magnesium, sodium, bicarbonate, and boron. County agents and Soil Conservation Service representatives may be consulted for information on the analysis of samples and an explanation of the results obtained.

Tests for salt-affected soils have been developed by the Salinity Laboratory and are available in U. S. Department of Agriculture Circular 982, Tests for Salinity and Sodium Status of Soil and Irrigation Water. By adequate testing, the soil and water management can be adjusted so as to keep a soil free from salt, or to prevent slightly salt-affected soil from becoming seriously affected with salt.