TOLERANCE of Crops to EXCHANGEABLE SODIUM

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TOLERANCE of crops to EXCHANGEABLE SODIUM

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WHAT IS EXCHANGEABLE SODIUM?

Exchangeable sodium is that fraction of the soil sodium that is adsorbed by the soil and may be replaced by, or exchanged with, other salt constituents, such as calcium or magnesium.

Irrigation water contains dissolved salts that are dissociated, or separated, into ions. The most common ions in water include positively charged cations, such as calcium, magnesium, and sodium, and negatively charged anions, such as bicarbonate, chloride, and sulfate. As water containing dissolved salt passes through the soil, the positively charged cations are attracted to and held by the negatively charged silt and clay particles of the soil. Cations held on the surface of the silt and clay particles in this manner may be replaced by, or exchanged with, other cations in the irrigation water or soil solution and are referred to as exchangeable cations.

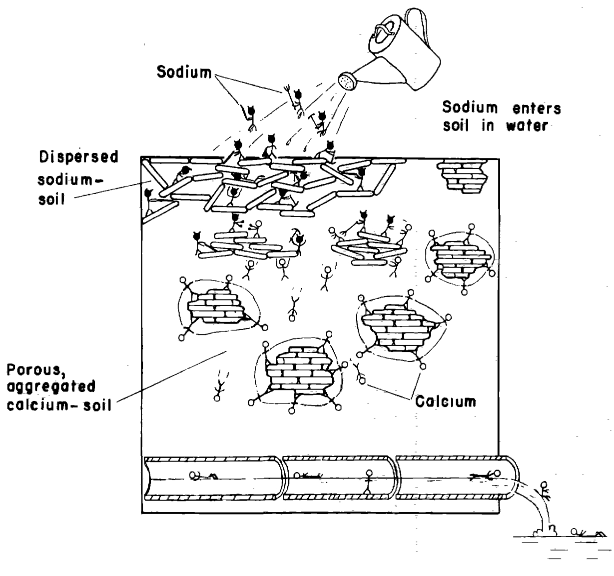
The amounts of the various cations held in an exchangeable form by the soil are related to the relative composition of the irrigation water. Thus, the continual use of an irrigation water containing a high proportion of sodium as compared to calcium and magnesium will eventually result in a soil containing excessive exchangeable sodium. Soils containing excessive exchangeable sodium are called sodic soils.[1]

HOW CAN SODIC SOILS BE RECOGNIZED?

Sodic soils usually take water slowly, crust when dry and are sticky when wet, and have a black surface.

As irrigation water containing a high proportion of sodium passes through a soil, the sodium displaces a part of the calcium and magnesium adsorbed onto the surface of the soil particles. The adsorbed sodium causes the soil particles to disperse, or deflocculate. In extreme cases the soil particles may be completely dispersed. The disperson of soil particles results in a soil having very small pores. Thus, just as it is relatively more difficult for water to pass through sand than through gravel, it is difficult for air and water to move through sodic soil. Sodic soils should not be confused with fine-textured soils (high clay content), which may also take water slowly.

Soils affected by exchangeable sodium are difficult to cultivate. Plowing or cultivating dispersed soils that are too dry results in large clods that are hard to break. If these soils are too wet, they are very sticky. Thus, it is difficult to form



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 smaller pores, through which water moves slowly.

[1] Sodic soils are sometimes referred to as sodium, alkali, or black alkali soils. Localized areas of sodic soils are called slick spots.

a good seedbed or to cultivate satisfactorily. Soil particles of sodic soils tend to adhere to each other when wet and form a very hard crust as the surface dries out.

In sodic soils, the organic matter dissolves. As these soils dry out, this dissolved organic matter moves upward and is deposited as a black coating on the surface of the soil.

Chemical analysis is the only positive way to identify sodic soils. Information concerning the analysis of soils and the interpretation of the results may be obtained from county agents or Soil Conservation Service representatives. Also, this information is contained in U.S. Department of Agriculture Circular 982, Tests for Salinity and Sodium Status of Soil and Irrigation Water.

HOW DOES EXCHANGEABLE SODIUM AFFECT CROP YIELD?

Crop yields are reduced because of spotty stand and retarded growth.

Exchangeable sodium causes the soil particles to disperse, which results in smaller pores. Problems concerning aeration, water movement, and root growth are associated with these changes in the physical condition, or structure, of the soil.

The hard crust that frequently forms on the surface of a sodic soil as it dries out often hinders the emergence of young seedlings. Irrigating usually prevents the formation of such a crust. However, because of the small pores in a sodic soil, it is sometimes difficult to avoid the complete displacement of the soil air with irrigation water. If the water does completely displace the air, lack of oxygen may reduce germination.

Sodic soils, moreover, may restrict root elongation and development of young seedlings. This reduced root growth is related to the poor structure and restricted water movement into and through sodic soils due to the dispersion of the soil particles. As with germination, too much water will result in an aeration problem. In addition to growth problems related to the poor structure of sodic soils, there may be nutritional problems.

The soil solution of a sodic soil contains less calcium than sodium. Experimental results indicate that the growth of plants is related to the composition of the soil solution. The nutritional problems encountered on sodic soils, therefore, are usually related to the accumulation of calcium and sodium by plants. Plants grown on a sodic soil generally have a lower calcium content than those

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An irrigated pasture affected by exchangeable sodium. The spotty stand, black surface due to dissolved organic matter, and water standing in the furrows are indications of exchangeable sodium.

grown on a nonsodic soil, or on a soil having less exchangeable sodium. Plants with a high calcium requirement may actually suffer from a calcium deficiency when grown on sodic soils. Also, plants grown on sodic soils usually have a higher sodium content than those grown on nonsodic soils. Deciduous fruit and nut trees, which are specifically sensitive to sodium, may even accumulate toxic amounts of sodium when grown on soils that are not considered to be sodic on the basis of the percent exchangeable sodium. Excessive sodium in the leaves causes them to burn progressively inward from the tip or edges and drop from the tree. If this condition continues, it eventually kills the tree.

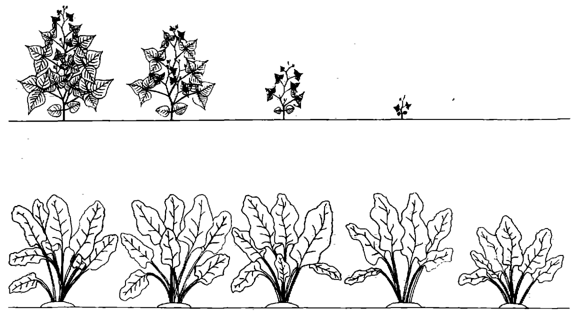
HOW MUCH EXCHANGEABLE SODIUM CAN CROPS TOLERATE?

The tolerance levels for various crops vary widely according to their specific sensitivities to adverse nutritional factors and adverse physical conditions of the soil.

Nutritional problems in sodic soils are usually related to the relative amounts of calcium and sodium accumulated by the plants. That is, the tolerance of crops is not so closely related to the absolute amount of exchangeable sodium (ES) in the soil as to the exchangeable-sodium-percentage (ESP), or the percentage of the total exchangeable cations that are sodium cations. Some crops are much more tolerant of a soil low in calcium or high in sodium than other crops.

At a given ESP, the physical condition of the various types of soils differs markedly. For example, the structure of a fine-textured (clay) soil is usually worse than that of a coarse-textured (sandy) soil. This difference in structure is related to the greater number of fine particles that can be dispersed in a clay soil. Some crops are more sensitive to inadequate moisture and hindrance to normal root development caused by adverse physical conditions than others.

The growth of plants most sensitive to exchangeable sodium is retarded even when grown on soils in which the adverse physical effects due to exchangeable sodium are not noticeable. The tree crops that are specifically sensitive to sodium may accumulate sufficient sodium to cause a burning and shedding of the leaves. The retarded growth of moderately tolerant crops is due in part to the nutritional problems associated with sodic soils and in part to the adverse structural characteristics of such soils. Most crops are moderately tolerant to exchangeable sodium. The most tolerant crops are apparently not affected nutritionally at even moderately high ESP values, but are retarded as a result of poor physical condition of the soil. The reduced growth of crops grown on sodic soils may, therefore, be due to adverse nutritional factors, adverse physical condition, or a combination of both.



Increasing exchangeable sodium (left to right) progressively stunts growth. Beans (above) are much more sensitive than beets (below).

Because of the variations in the structure of sodic soils due to texture, the tolerance of crops to exchangeable sodium is frequently based on nutritional responses in the absence of an adverse physical condition. The crops listed in table 1 have been studied under these conditions at the U.S. Salinity Laboratory and several State experiment stations. They are arranged approximately in order of increasing tolerance to exchangeable sodium.

TABLE 1.—*Tolerance of various crops to exchangeable-sodium-percentage*

Tolerance to ESP [1] and range at which affected	Crop	Growth response under field conditions
Extremely sensitive (ESP=2–10)	Deciduous fruits Nuts Citrus Avocado	Sodium toxicity symptoms even at low ESP values.
Sensitive (ESP=10–20)	Beans	Stunted growth at low ESP values even though the physical condition of the soil may be good.
Moderately tolerant (ESP=20–40)	Clover Oats Tall fescue Rice Dallisgrass	Stunted growth due to both nutritional factors and adverse soil conditions.
Tolerant (ESP=40–60)	Wheat Cotton Alfalfa Barley Tomatoes Beets	Stunted growth usually due to adverse physical condition of soil.
Most tolerant (ESP=more than 60)	Crested and Fairway wheatgrass Tall wheatgrass Rhodes grass	Do.

[1] ESP=exchangeable-sodium-percentage.

Table 1 considers only the nutritional factor. The physical condition of the soil as it relates to structure and the movement of water through the soil must also be evaluated before it is possible to determine whether a particular crop may be grown successfully at a given level of exchangeable sodium. Certain measuring methods, such as the degree of aggregation or hydraulic conductivity, are used in determining the physical condition of the soil. The measurement of the modulus of rupture indicates the crusting tendencies of a soil. The procedures to follow in making these measurements are explained in U.S. Department of Agriculture Handbook 60, Diagnosis and Improvement of Saline and Alkali Soils.[2]

WHAT ARE THE EFFECTS OF SALINITY ON A SODIC SOIL?

At a given ESP, salinity generally improves the physical condition and the calcium-supplying power of a sodic soil.

Soluble salts tend to flocculate (hold together) the soil particles; this counteracts, in part, the dispersing effect of exchangeable sodium. Flocculation increases the permeability of the soil to water and also makes the soil easier to cultivate. However, if the soluble salts are leached out of the soil while the exchangeable sodium is still on the clay particles, the soil will become dispersed; this will leave it in a poor physical condition.

At least part of the soluble salt in a saline soil is calcium. Thus, the calcium-supplying power at a given ESP is greater in the presence of salinity than in the absence of it. Nutritional problems related to the low calcium content of sodic soils are, therefore, not so severe or may even be lacking.

These effects of salinity on a sodic soil do not mean that normal yields may be expected, but, rather, that the adverse effects of exchangeable sodium on growth may not be so severe. Not only the exchangeable sodium but also the salinity conditions somewhat limit plant growth. The relative importance of either in limiting plant growth depends on the salinity and exchangeable sodium levels and on the plant tolerance to each.

HOW CAN CROP GROWTH BE IMPROVED ON SODIC SOILS?

Crop growth can be improved by soil reclamation and proper management practices.

The physical condition of sodic soils may be improved by partial or complete replacement of the exchangeable sodium by calcium. This can be done by adding to the soil a source of soluble calcium or an amendment that will dissolve calcium compounds already present in the soil. The techniques and materials that may be used in reclaiming sodic soils are described in U.S. Department of Agriculture, Agriculture Information Bulletin 195, Chemical Amendments for Improving Sodium Soils.

The sodium that has been replaced by calcium must be leached out of the soil to prevent it from again replacing the calcium. Leaching is frequently done by ponding water on the surface of the soil. While leaching the soil, it may be possible to grow rice, a crop that can be grown on submerged soils. Rice is moderately tolerant to exchangeable sodium but quite sensitive to salinity. If the sodic soil being reclaimed is also saline, rice may not survive.

[2] This handbook may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D.C. for $2.00 a copy.

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