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# SALT TOLERANCE of PLANTS

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# SALT TOLERANCE OF PLANTS

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## SALINITY: WHAT IT IS AND HOW IT IS MEASURED

The term "salt," as used by the chemist, applies to a long list of substances of which sodium chloride (common table salt) is the best known. Most chemical fertilizers supply essential plant nutrients in the form of salts. As examples, calcium nitrate supplies calcium and nitrogen, and potassium sulfate supplies potassium and sulfur.

Nutrients are normally available to plants in the form of soluble salts in the soil. However, too great a supply of salts in the soil can be harmful to plants. When soluble salts are present in such an excess that they injure plants, the soil is said to be *saline*.

In the field, the various salts—chloride, sulfate, and bicarbonate salts of sodium, calcium, and magnesium—contribute in varying degrees to soil salinity. Also, the proportions of the different salts vary widely in different places. Salts occur in the soil primarily from the weathering of rock, but they are often transported to a locality by moving surface or ground waters.

Salts accumulate, especially in arid regions, because rainfall is insufficient to leach them out of the soil, and because surface drainage is often inadequate to carry the dissolved salts into the sea.

In areas of intensive agri-

culture, and quite often in greenhouse operations, high levels of fertilization may cause an accumulation of soluble fertilizer salts to the point where salinity may seriously affect production.

### Measuring salinity

Salt molecules, in solution, split up to produce electrically charged particles called ions. For example, each molecule of sodium chloride produces one positive sodium ion and one negative chloride ion. The ions can carry, or conduct, an electrical current—the greater the concentration of ions in a solution, the greater the conductivity of the solution.

The total concentration of ions in the soil water usually has more influence in affecting plants than the precise composition of the solution. Thus, for most purposes, the salinity of a soil can be determined by measuring the electrical conductivity, in this way:

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#### SALINITY TESTING SERVICE

Soil salinity tests are routinely performed by soil-testing laboratories in salt-affected areas. Information regarding local availability of this service may be obtained from county agricultural agents, State farm advisors, or State experiment stations.

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A sample of the soil to be tested is saturated with distilled water. Some of the solution from the resulting soil paste is extracted on a suction filter.<sup>1</sup> This solution is called the *saturation extract*. The salt content of the saturation extract may then be measured by determining the extract's capacity to conduct an electrical current.

The symbol for *electrical conductivity of the saturation extract* is  $EC_e$ . The conductivity is measured in millimhos per centimeter (mmhos./cm.). Thus, 2 mmhos./cm.,  $EC_e$ , means that 2 millimhos per centimeter is the electrical conductivity of the saturation extract. These are the usual terms in which soil salinity is reported.

The relationship of  $EC_e$  to plant-growth effects is shown in table 1.

#### Value of salinity tests

If salt injury is suspected, salinity should be determined by carefully sampling the soil from the root zone of affected plants and testing it to measure the  $EC_e$ .

If the salinity is found to be in a range injurious to the crop, according to table 1 (or according to the salt-tolerance information that follows), appropriate

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<sup>1</sup> USDA Circular 982, "Tests for Salinity and Sodium Status of Soil and of Irrigation Water."

TABLE 1.—Crop response to salinity

Soil salinity is determined by finding the electrical conductivity of the soil saturation extract (EC). The electrical conductivity is measured in millimhos per centimeter (mmhos./cm.). One mmho./cm. is equivalent, on the average, to 640 p.p.m. of salt.]

Salinity (EC, mmhos./cm. at 25° C.)	Crop responses
0 to 2.....	Salinity effects mostly negligible.
2 to 4.....	Yields of very sensitive crops may be restricted.
4 to 8.....	Yields of many crops restricted.
8 to 16.....	Only tolerant crops yield satisfactorily.
Above 16.....	Only a few very tolerant crops yield satisfactorily.

remedial measures should be started. Heavy irrigation will leach the salt out of the soil if soil drainage is adequate. Often, drainage must first be improved by tiling, ditching, or pumping the ground water before leaching can take place.

## HOW SALINITY AFFECTS PLANTS

### General effects

Plants that are salt sensitive or only moderately tolerant show a progressive decline in growth and yield as levels of salinity increase. When salinity reduces growth, plant parts

### SALINITY MEASUREMENT EXAMPLE

To visualize the amount of salt represented by an electrical conductivity of 1 millimho per centimeter of soil extract (1 mmho./cm., EC<sub>e</sub>), imagine that you have a 50-gallon barrel of pure water, and that you dissolve in it 4 ounces of table salt. *The salt concentration of the solution would be approximately 640 parts per million.* If you used this water to saturate a sample of salt-free soil, the solution extract would have a conductivity of about 1 millimho per centimeter.

Salinity tests also indicate whether a field may be planted directly or whether preliminary leaching is necessary to remove excess salt.

Periodic measurements of soil salinity show whether salinity is increasing; thus, damage may be averted by timely improvement of irrigation practices.

such as leaves, stems, and fruits are usually smaller than normal. The leaves are often a characteristically deeper blue-green color.

With some plants—corn, al-

falfa, and beans, as examples—yields are generally reduced in rough proportion to the decrease in plant size. With barley, wheat, cotton, and the more tolerant grasses, however, the yield of seed or fiber may not decline even when salinity causes a decrease of as much as 50 percent in plant size.

Salinity often restricts plant growth severely without the development of any acute injury symptoms. When this happens, it may lead to considerable loss of yield, and the grower may not realize that salinity is responsible. In most cases, however, soil salinity in a field will be so variable that bare spots or areas of severely stunted plants, and perhaps spotty stands, will occur; all are signs of possible salt damage.

### Nutritional effects

Salinity sometimes interferes with normal plant nutrition.

High concentrations of calcium ions in the soil solution may prevent the plant from absorbing enough potassium, or high concentrations of other ions may affect the uptake of sufficient calcium.

Different crops vary widely in their requirements for given nutrients, and in their ability to absorb them. Nutritional effects of salinity, therefore, appear only in certain crops, and only when a particular type of saline condition exists.

Some varieties of a particular crop may be immune to nutritional disturbance, while other varieties are severely affected. High levels of soluble sulfate cause internal browning (a calcium-deficiency symptom) in some lettuce varieties but not in others. Similarly, high levels of calcium cause greater nutritional disturbances in some carrot varieties than in others. Chemical analysis of the plant



BN-19598

Bare spot with salt-tolerant weeds in a cornfield near Santa Ana, Calif.



BN-5502

The poor, spotty stand of beans indicates soil salinity in this California field.

is useful for diagnosing these effects.

At a given level of salinity, growth and yield are depressed more when nutrition is disturbed than when nutrition is normal. Nutritional effects, fortunately, are not important in most crops under most saline conditions; when they do occur, the use of better-adapted varieties may be advisable. Spraying affected plants with solutions of the deficient nutrient may also correct the disorder. Increased incidence of blossom-end rot of tomatoes under saline conditions has been controlled by spray applications of calcium salts.

### Toxic effects

Any salt that is present in the soil in excess may be considered "toxic." However, it is better to apply this term to only those ions that cause characteristic and acute plant injury.

Such injury is quite widespread among fruit and nut crops, woody ornamentals, and shade trees. When the leaves of these plants accumulate more than  $\frac{1}{4}$  percent of sodium or  $\frac{1}{2}$  percent of chloride (dry-weight basis), characteristic leaf-injury symptoms generally appear. The tips or margins of the leaves are usually affected first. Death of these tissues and the bleaching out of the leaf pigments result in a marginal or tip burn. The affected tissues become tan or brownish, and are sharply separated from the healthy part of the leaf, which usually retains its normal green color. The higher the level of chloride or sodium accumulation in the leaf, the larger the extent of the burned leaf tissue.

Berries, grapes, stone fruits (such as plum, peach, and apricot), citrus, avocado, and pecan—all are injured when critical levels of chloride or sodium ac-





89-1501

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

accumulate. In citrus and in some shrubs a bronzing of the leaves is caused, followed by early leaf drop; leaf burn may not occur.

Excess boron causes leaf-burn symptoms that are described in another bulletin.<sup>2</sup> All crops are susceptible to excess-boron injury.

Some varieties of a given crop take up chloride or sodium more rapidly than do other varieties, and are injured more severely. Also, different rootstocks for crops such as citrus or stone fruits vary in their rates of absorption, and hence in susceptibility.

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<sup>2</sup> USDA Agriculture Information Bulletin 211, "Boron Injury to Plants."

The effects of leaf burn on yield are also variable. In grapes or blackberries, the development of leaf burn may have a critical effect on yield. In strawberries, however, leaf burn is relatively unimportant because the general salt effect in itself restricts growth severely.

For ornamentals and fruit crops susceptible to chloride or sodium toxicity, a knowledge of total salinity does not always suffice for a diagnosis of the problem. The concentration of chloride and sodium in the soil water surrounding the roots must also be considered. Similarly, in judging the suitability of an irrigation water the concentrations of these ions and

possible toxic effects must be considered in addition to the total salt concentration of the water.

Almost all minerals found in plants are normally absorbed through the roots. However, leaves may also absorb large amounts of the minerals; this occurs when the foliage is wetted by sprinklers. Waters containing as little as 3 milliequivalents per liter of sodium or chloride (equivalent to about 70 p.p.m. of sodium or 100 p.p.m. of chloride) may cause this injury.

The leaves of stone-fruit and citrus trees absorb sodium or chloride very rapidly. Therefore some waters that are entirely suitable when applied to the soil cause severe damage if they wet the leaves. Straw-

berry leaves absorb sodium or chloride more slowly, and avocado leaves practically not at all. These crops may be sprinkled without concern for salt uptake by the leaves.

Other crops are not specifically sensitive to sodium or chloride. Vegetable, forage, and field crops often accumulate these elements up to 5 percent and sometimes 10 percent of the dry weight of their leaves without developing leaf-injury symptoms. Sprinkling these crops, therefore, does not create the potential toxicity hazard noted for fruit crops and other susceptible species. Care must always be taken to irrigate sufficiently to prevent salt accumulation in the soil, regardless of what irrigation method is used.

## SALT TOLERANCE DATA

### Growth stages and salt tolerance

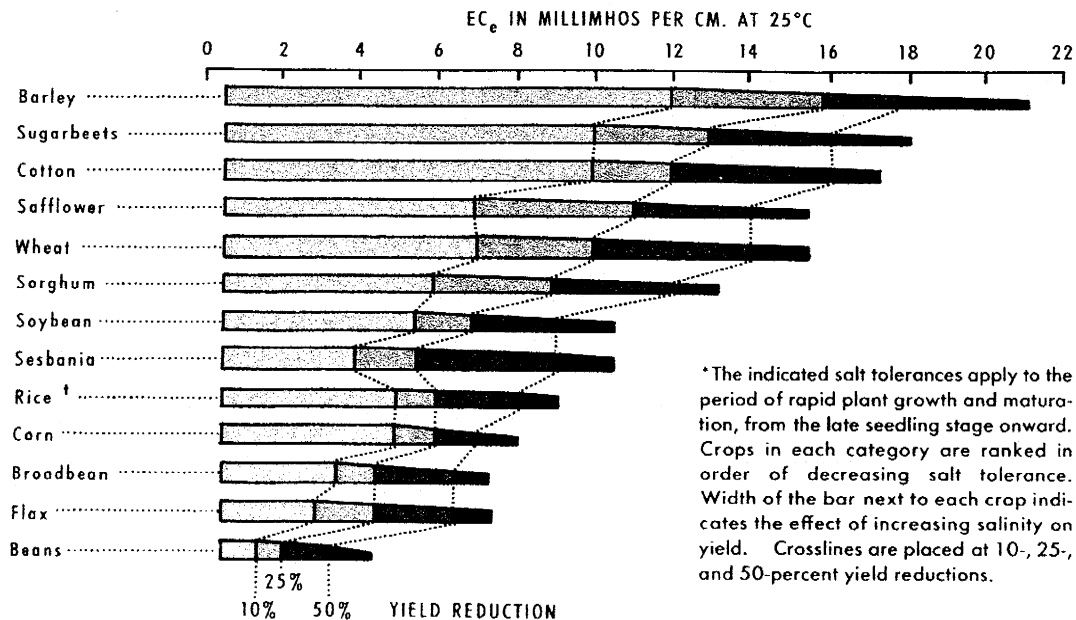
Some crops are affected by salinity more at one stage of development than at another. Even highly tolerant crops may be acutely affected at some particular stage.

Sugarbeets are sensitive to salinity during germination; barley, wheat, rice, and sesbania are affected more during early seedling growth than during germination or later growth

stages. Rice also is sensitive during flowering and seed set. EC<sub>e</sub> generally should not exceed 4 millimhos per centimeter during the sensitive stages, regardless of the plant's higher tolerance at other stages.

Well-established plants will usually be more tolerant than new transplants. This fact is of considerable importance for plants propagated by transplanting, such as cabbage, other

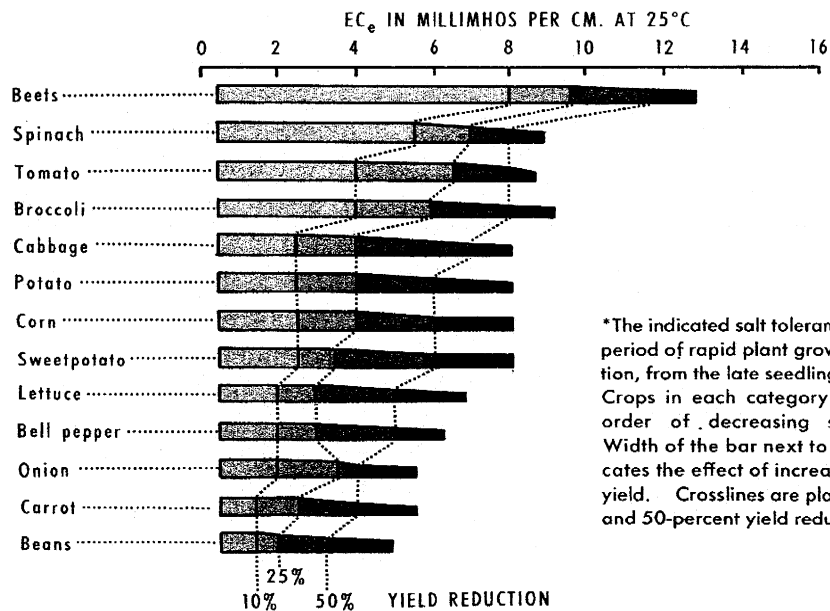
## SALT TOLERANCE OF FIELD CROPS\*



\*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50-percent yield reductions.

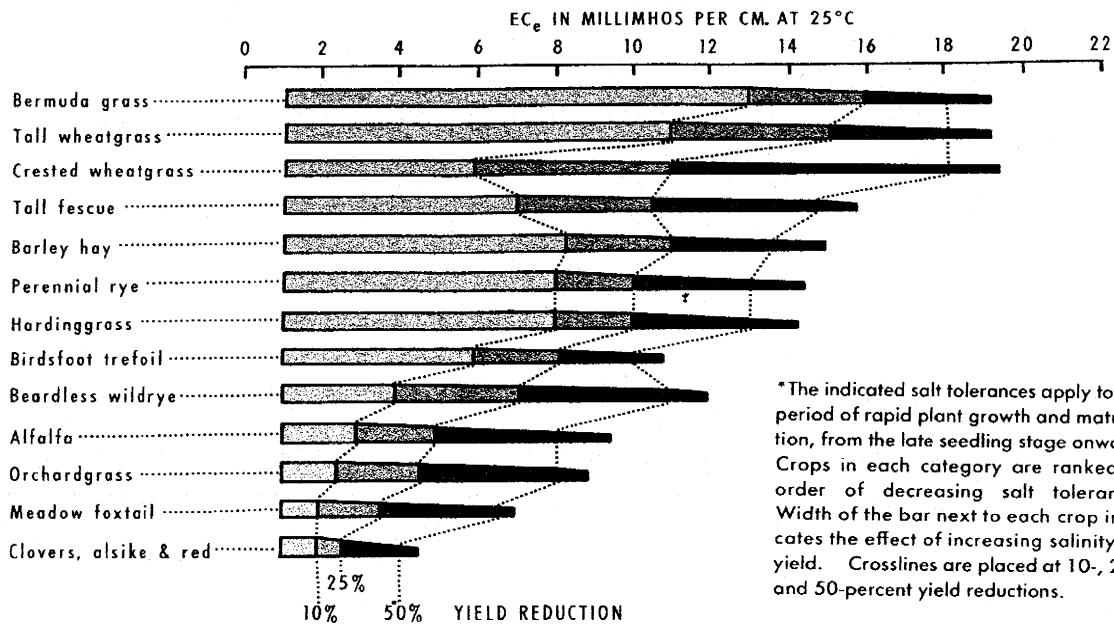
† PADDY

## SALT TOLERANCE OF VEGETABLE CROPS \*



\*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50-percent yield reductions.

## SALT TOLERANCE OF FORAGE CROPS\*



cole crops, sweetpotatoes, and tomatoes.

Salt tolerances of important crop plants are shown in the accompanying diagrams. The indicated tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Information regarding special sensitivity during germination and early seedling growth should also be taken into account.

These data were derived mainly from experiments in artificially salinized field plots. By these experiments, the yield and  $EC_e$  relationships were established. High yields under nonsaline control conditions were obtained by maintaining growing conditions that were optimal with regard to such factors as fertilization, irrigation, and pest control.

If, under ordinary field conditions, any condition such as insufficient fertilization restricts growth, salinity effects may not appear at the lower salinity levels as indicated in the diagrams. This is because the deficient condition will be controlling growth. Conversely, if excessive salinity is reduced, yield increases will appear only if all other conditions are favorable for the higher yields.

Varieties of any one crop are usually so similar in salt tolerance that varietal differences may be ignored in most crops. Among forage crops, however, significant varietal differences do occur. Coastal and Suwanee bermuda grasses decrease 50 percent in yield at an  $EC_e$  of about 21 millimhos per centimeter; Common, Greenfield, and Northrup King 37 decrease 50



BN-8180

Field-plot studies on the salt tolerance of vegetable crops at the U.S. Salinity Laboratory, Riverside, Calif. In the foreground are shown five varieties of peppers on four plots adjusted to graded salinity levels.

percent at an  $EC_e$  of 15 millimhos. Broadleaf strains of smooth bromegrass are more tolerant than narrow-leaf strains, but narrow-leaf birds-foot trefoil is more tolerant than the broadleaf variety. The tolerances given in the diagrams for these crops represent average values. (Bromegrass is somewhat less tolerant than orchardgrass.)

Most fruit crops are more sensitive to salinity than are field, forage, or vegetable crops. Rootstock and varietal differences in salt tolerance of fruit crops are so large that it would be meaningless, for most, to give crop tolerances.

The date palm, however, is tolerant; and the pomegranate, fig, olive, and cantaloup are less tolerant in that order. The tolerable levels of salinity, at which only minor reductions in yield may be expected, range from about 8 to 10 millimhos per centimeter for the date palm to only 3 millimhos for cantaloup.

Grapes, citrus, stone fruits, pome fruits, berries, and avocados are all relatively sensitive to salinity; their tolerance decreases in approximately the order given. The range of tolerable salinities is from about 4 millimhos per centimeter to 1.5 millimhos per centimeter. Critical chloride concentrations range from about 25 milliequivalents per liter (890 p.p.m. of

chloride) in the saturation extract to as low as 5 milliequivalents (180 p.p.m. of chloride). However, some varieties of grapes (Thompson Seedless, Perlette) absorb chloride more slowly than others (Cardinal, Black Rose) and should be classed as moderately tolerant.

Certain stone-fruit, citrus, and avocado rootstocks take up less chloride than do other rootstocks, and are therefore more salt resistant. Among the more tolerant rootstocks are some of the mandarins and mandarin-limes for citrus, Marianna for plum and prune, and West Indian for avocado. A plum or prune tree on a salt-tolerant root will be more tolerant than grapes or citrus on salt-sensitive roots.

### **Climate and salt tolerance**

Climate can affect the salt tolerance of plants. Generally, salinity tends to be more harmful under hot, dry conditions than under cool, humid conditions. Climate influences the salt tolerance of some crops more than others. Onions have been shown to be particularly sensitive in desert areas. The salt tolerances given in this bulletin prevail where growing conditions are best suited for the individual crops under irrigation.

Specific toxicity, especially that caused by chloride, is more

severe in hot, dry climates or during periods of high temperatures than it is under cool growing conditions.

### **Supplemental irrigation and salt tolerance**

Supplemental irrigation in humid regions very often increases yields by relieving drought. Often, in coastal areas, the waters available for irrigation are saline or brackish. Salinity can be tolerated better during a short period than during the longer period required for the development of the crop. If only one or two irrigations with saline water are needed to supplement rainfall, the damage from salinity may be much less than would be caused by drought in the absence of irrigation.<sup>3</sup>

### **Salinity of irrigation waters and salt tolerance**

No fixed relationship exists between the salinity of an irrigation water and its effect on plants. Only one limitation is predictable: Barring dilution of the soil solution by rain, salinity of the soil solution will be equal to or greater than that of the irrigation water. Salinity of the soil solution is almost always 2 or 3 times as great as

salinity of the applied irrigation water; often it is 5 to 10 times as great, and may be even greater.

The major factors in determining the degree of salinity increase are (1) The amounts of water applied in relation to water used by the crop and lost by evaporation, (2) drainage, and (3) height of water table. Depending on the evaluation of these factors, one must make reasonable allowance for salt accumulation in the soil in judging the suitability of an irrigation water for a particular crop.

In these computations, allowance must be made for the saturation extract having only about half the salt concentration of the soil solution at field capacity. With average irrigation regimes and drainage, a reasonable allowance would be for an EC<sub>e</sub> three times as high as the EC of the irrigation water, or for a soil solution at field capacity having six times the salinity of the irrigation water.

Special provisions or precautions may be necessary to prevent injury to the crop during its sensitive growth stages. For example, paddy fields may be drained and reflooded with fresh water to reduce salt concentrations during the critical flowering and grain-set stage of rice.

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<sup>3</sup> USDA Agriculture Information Bulletin 213, "Use of Brackish Water for Irrigation in Humid Regions."



## SALINITY EFFECTS ON CROP QUALITY AND COMPOSITION

Salinity has various effects on crop quality. It generally causes decreases in the size, quality, and market value of fruits (tomatoes, cucumbers, and others), marketable heads (cabbage, lettuce), and roots (carrots, yams). Salinity also causes some positive effects. It increases the sugar content quite markedly in some crops; for example, it contributes to the production of sweeter carrots and cataloups.

When overgrowth is a potential cause of impaired quality, as with split or divided onion

bulbs, low salinity levels will check the growth slightly and may prevent the damage. Cabbage heads from saline plots are firmer and more solid than others. All of these beneficial effects of salinity are usually associated with some decrease in yield.

Caution must be exercised in any attempt to use salinity to improve quality, because severe losses can result if salinity becomes excessive. Also, many of the benefits induced by salinity can be obtained more safely by irrigating less frequently dur-



BN-6625

Test plots for studying the salt tolerance of grasses and forage legumes. Legumes on moderately saline plots are stunted or killed, while those on alternate nonsaline plots are making vigorous growth.

ing the development or maturation of the crop. In many respects, moisture stress and salinity affect plants similarly.

Among field crops, quality effects are less conspicuous than among vegetable crops. Fiber quality of cotton is only slightly affected by salinity, and grain quality of barley and wheat seems to be unaffected. These are also tolerant crops that produce full yields at moderate salinities up to 8 to 10 millimhos per centimeter,  $EC_e$ .

The quality of forage crops is sometimes strongly affected by salinity. Fruit and seed normally accumulate very little salt, but leaves and stems often do. Some species that are highly salt tolerant, such as Rhodesgrass, may cause scouring in cattle because the hay produced on saline soils contains too much salt.

Other salt-tolerant grasses, notably bermudagrass and tall wheatgrass, take up relatively little salt and produce good hay or forage on saline lands. In-

creased toughness of some grasses under saline conditions decreases their palatability for livestock, but the highly tolerant species that make normal growth under moderately or even highly saline conditions (up to 15 millimhos per centimeter,  $EC_e$ ) are not so affected. Increased toughness tends to occur in proportion to growth inhibition.

Relatively little is known about the effects of salinity on fruit crop quality. Leaf burn and leaf drop caused by salinity often expose the fruit to the sun, and result in sun scald. Smaller than normal fruit size may occur because of salinity, but this is a consideration of less importance for fruit crops than for vegetable crops; the greater sensitivity of fruit crops generally restricts their culture to a much smaller salinity range. For the same reason, the effects of salinity on acids or sugars are less likely to occur in fruits than in the more tolerant vegetables.

## SODIUM EFFECTS ON SOIL AND PLANTS

Special attention is given to sodium because it can induce marked changes in soil characteristics that directly affect plant growth. The cations (electrically positive ions) calcium, magnesium, sodium, and

potassium, are attracted and held (adsorbed) by negative electrical charges of the soil.

Calcium and magnesium normally comprise the major part of adsorbed ions in productive soils in arid and semiarid re-

gions. These adsorbed ions can be replaced or exchanged by other cations, and hence are referred to as "exchangeable cations."

When a soil having a preponderance of adsorbed calcium and magnesium is irrigated with water in which sodium strongly predominates, some of the calcium and magnesium is replaced by sodium. When sodium occupies about 15 percent of the total exchange capacity of the soil, the structure of the soil begins to break down. Aggregates, or soil crumbs, break up; the soil becomes dispersed, and permeability to air and water decreases markedly. Such a soil is termed a "sodic soil"; because of its poor physical condition, most plants cannot be economically grown in it.

Since exchangeable calcium and magnesium decrease as the proportion of sodium increases, nutritional factors may become important even before the physical condition of the soil deteriorates. Thus, beans are affected at exchangeable sodium percentages near 10 percent.

Sodium toxicity may become a factor for sodium-sensitive

fruit crops such as avocados, stone-fruits, and citrus when exchangeable sodium is as low as 5 percent. But for most crops the poor physical condition is the restrictive factor in sodic soils, and elimination of the sodium by replacement with calcium is necessary before the land can be used successfully. The calcium is supplied by soil amendments such as gypsum, or by treating the soil with acid or acid-forming amendments to release calcium from insoluble lime.<sup>4</sup>

Because of the effects of sodium on the soil, special attention is given also to the proportion of sodium in irrigation waters. The sodium-adsorption-ratio for an irrigation water is usually calculated, and from this calculation the ultimate level of exchangeable sodium in the soil can be predicted.<sup>5</sup> Exchangeable-sodium percentages in soils are determined by displacement and measurement of the exchangeable sodium; it is expressed as a percentage of the exchange capacity of the soil, which is determined on a separate soil sample.

## MANAGEMENT IN RELATION TO SALINITY CONTROL

Modifications in fertilization, planting methods, and irriga-

tion practices can significantly change plant response to salin-

<sup>4</sup> USDA Agriculture Information Bulletin 195, "Chemical Amendments for Improving Sodium Soils."

<sup>5</sup> USDA Agriculture Information Bulletin 197, "Determining the Quality of Irrigation Water."

ity. The effects of fertilizer levels have already been indicated, and the cited salt-tolerance values are based on the assumption that nearly optimal levels of fertilization have been provided. The remaining factors—irrigation and planting—are fully as important, and may even be decisive in their influence on plant response.

### **Irrigation frequency**

Plant response is governed primarily by the total concentration of dissolved salts in the soil water. During an irrigation cycle plants absorb water from the soil solution, but they absorb relatively little of the salt contained therein. As a result, the soil solution becomes progressively more concentrated as soil water is depleted by plant uptake and evaporation. The higher salt concentrations developing prior to each irrigation exert their effects on the plant, and the ultimate plant response and yield are determined by a summing up of all the short-term responses.

If irrigation is relatively infrequent, the concentration of the soil solution will increase considerably before reirrigation dilutes it again. The average concentration of the soil solution and the effects on the plant will be correspondingly greater than when more frequent irrigation is practiced.

It follows directly that growth

and yield will be better if irrigation is more frequent—assuming, of course, that frequency of irrigation is not carried to the point of affecting the crop adversely by excessive watering.

The foregoing recommendation may be stated in terms of the need for irrigating saline soils at a higher residual moisture content than may be required for the same soils under nonsaline conditions. That is, soil should not be allowed to become as dry when it is saline as when it is nonsaline.

Actually, it is found that most crops deplete the soil water more slowly under saline conditions than under nonsaline conditions. This is caused primarily by slower plant development and smaller plant size under saline conditions. Because of this slower rate of moisture depletion, growers may be tempted to defer irrigation until the soil becomes drier. This is unwise. It is desirable to irrigate the saline soil at the same frequency as the nonsaline, despite the higher moisture content remaining in the saline soil at the time of irrigation.

For the increasing number of growers who are now using soil moisture-measuring devices (tensiometers) as a guide to irrigation, it will suffice to say that irrigation under saline conditions would usually be required

well before full-scale readings, equivalent to about one bar (atmosphere) moisture tension, are recorded. In many cases, tensions of only one-fifth to one-third bar (one-fifth to one-third full-scale tensiometer readings) are recorded at the time when moisture tension in comparable nonsaline soil, with the same crop, has reached or exceeded the one-bar tension (full-scale tensiometer reading).

Some exceptions occur. Highly salt-tolerant plants such as bermudagrass and tall wheatgrass will deplete soil moisture as rapidly under saline as under nonsaline conditions. In these cases, full-scale tensiometer readings may be obtained before irrigation is necessary.

### **Irrigation amounts**

The amount, or depth, of water applied influences salinity directly. Let us suppose that only enough water is applied in each irrigation to replace that which has been lost by *consumptive use*—that is, by the amount of water which has been absorbed by the plant and lost by evaporation. Then each irrigation will introduce an additional quantity of salt, and this salt will be added to that already present in the soil. Soil salinity will increase, therefore, with each irrigation, and even waters of moderate salt content

may produce prohibitively high soil salinities within one irrigation season.

It is therefore necessary to add more water than has been lost by consumptive use. This additional water will serve to leach the salt downward and restrict salt accumulation in the root zone of the crop. The extra water needed for leaching, expressed as a fraction of the total water penetrating the soil, is called the "leaching requirement."

It is obvious that the leaching requirement would be zero if pure water, free of salt, were available. The leaching requirement increases in direct proportion with the salinity of the irrigation water. It is found by dividing the salinity of the irrigation water by the salinity at which one gets a 50-percent yield decrease for the crop in question.

Thus, if one is irrigating alfalfa with a 1-millimho-per-centimeter water, the leaching requirement would be  $\frac{1}{8}$ , since alfalfa yields decrease 50 percent at an  $EC_e$  of 8 millimhos per centimeter. When  $\frac{7}{8}$  of the total water penetrating the soil has been taken up by the plant, or evaporated, the remaining  $\frac{1}{8}$  of the water will have an EC of 8 millimhos per centimeter, the maximum permissible level. This high salinity will occur only at the bottom of the root zone, with lower salinities in the rest

of the root zone. Under such conditions, only small yield reductions will occur.

The total depth of irrigation water needed can be figured by subtracting the leaching requirement from 1 and dividing this value into the consumptive use figure for the crop. If the consumptive use for alfalfa is 42 inches, then the total depth of 1-millimho-per-centimeter water required is 42 divided by  $\frac{7}{8}$ , or 48 inches. One-eighth of the 48 inches, or 6 inches of water (the excess over consumptive use) will carry the 8-fold concentrated water below the root zone where it can be removed in the drainage system. An adequate drainage system is essential if the calculated control is to function properly.

With a given irrigation water, the leaching requirement is greater for crops that are more salt-sensitive. For red clover, which is only half as salt-tolerant as alfalfa, the leaching requirement is twice as great. On the other hand, for bermudagrass, which is twice as salt-tolerant as alfalfa, the leaching requirement is only half as great as for alfalfa.

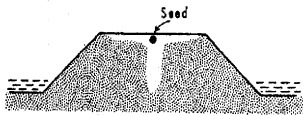
### **Planting practices and germination**

Although salt tolerances during germination and later growth stages are essentially equal for most species, salt problems during germination

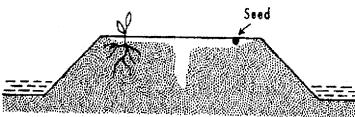
are often most troublesome. This stems from the fact that salt concentrations often build up very markedly in the surface inch or so of soil because of continued evaporation and upward movement of the soil solution. The germinating seed may therefore be exposed to salt concentrations several to many times as great as those encountered by the roots at later growth stages.

This factor is generally not important in flooded or basin-irrigated soil unless considerable time elapses between the last irrigation and seed germination. In furrow-irrigated row crops, on the other hand, salt accumulation around the seed occurs very commonly. Water moving into the ridges carries the salt into the center and crown of the bed so that salt concentrations in the center of the bed regularly become 5 to 10 times as great as the original concentration in the plow layer. An initial salinity of only 1 millimho per centimeter, EC<sub>e</sub>, can become 5 to 10 millimhos per centimeter following a single irrigation.

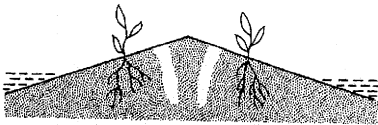
This salinity can be inhibitory for crops such as beans and sugarbeets, and severely retard germination of most other row crops. The margin of safety for single-row crops is therefore extremely narrow, and frequent stand failures are



Single-row bed. Germination failures are frequent, even if soil is only slightly saline at time of planting.



Double-row bed. Germination is affected at moderate salinity levels.



Sloping bed. Germination is rarely affected by salt initially present in soil.

Zones of salt accumulation

Diagrams showing areas of salt accumulation in raised beds with different planting practices. BN-8381

to be expected. Salt build-up is less near the shoulders of the bed than at its center. With double-row plantings, initial salinities in the plow layer of about 2 to 5 millimhos per centimeter can be tolerated. Salinity around the seed after irrigation will generally not exceed the initial value in the plow layer and will often be somewhat less.

Plantings on sloping beds are favored by the fact that the advancing water front sweeps salt past the seed instead of up to it. Salinity is therefore least troublesome when properly shaped sloping beds are used. Normal germination has been obtained when initial salinity of the plow layer was as high as 40 millimhos per centimeter,  $EC_e$ , which is approximately

the salinity level caused by flooding land with sea water. Of course, water of good quality was used in irrigating these plantings in saline soil. It is usually the initial salinity of the soil present at the time of planting, rather than the salt in the irrigation water, that causes trouble during germination.

The range of salt tolerance among plants during germination is about the same as the range during later growth stages. Crops that are very sensitive during germination are affected by  $EC_e$ 's of about 3 or 4 millimhos per centimeter. The most tolerant ones (barley, rice) can germinate at  $EC_e$ 's of 15 to 20 millimhos per centimeter.

For most crops, one should

attempt to keep the  $EC_e$  below 4 millimhos per centimeter during germination and early seedling stages. This is true even for crops that can tolerate high salinity during later growth stages. The range of salinity possible with small changes in planting practices

(from a 10-fold increase in salinity to a 10-fold or greater reduction) suggests that control of salinity during germination is more feasible than during later periods, and should be regularly practiced to achieve good stands—the indispensable starting point for good yields.

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## SUMMARY

1. The electrical conductivity of the saturation extract of soils, a measure of total salinity, adequately describes the effective salt content of the soil for most crop situations. Since many fruit crops, trees, and shrubs are sensitive to chloride and sodium, the additional determination of these elements in the saturation extract is often advisable.

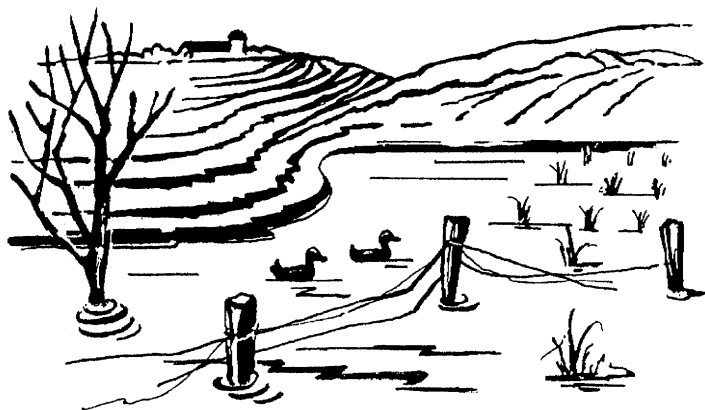
2. Analysis of plant samples is useful in detecting nutritional effects of salinity and in diagnosing toxic accumulations of chloride or sodium in fruit crops, trees, and shrubs.

3. The salt tolerance of plants varies widely, not only from crop to crop but in some cases even for a given crop, depending on its stage of growth. Salt-tolerance data are useful for the diagnosis of salt injury and in selecting tolerant crops for saline conditions.

4. Proper management practices, especially adequate irrigation and suitable planting techniques, can lessen the harmful effects of salinity. Improved yields will result from decreases in harmful salinity only if all other factors (fertility, insect and disease control, crop varieties, etc.) are adequate for higher yields.

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## **Conserve your soil and water**

Develop a farm or ranch conservation plan.

Use each acre within its capability.

Contour, strip crop, or terrace sloping land.

Plant and manage trees as a crop.

Improve range; manage grazing.

Encourage wildlife as useful and profitable crops.

Plant grass on idle land.

Use ponds to impound water.

Improve irrigation or drainage systems.

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