Agriculture Information Bulletin No. 292

SALT TOLERANCE of FRUIT CROPS

AGRICULTURAL RESEARCH SERVICE • UNITED STATES DEPARTMENT OF AGRICULTURE

SALT TOLERANCE OF FRUIT CROPS

By LEON BERNSTEIN, *Soil and Water Conservation Research Division, Agricultural Research Service*

What Is Salinity and How Does It Affect Fruit Crops?

Salinity is the presence of excess soluble salts in the soil. It stunts growth and causes leaf burn in many fruit crops.

Soluble salts provide mineral elements required by plants for normal growth. However, an excess of soluble salts is harmful, and plant growth generally decreases as salinity increases. The salt constituents (ions) usually found in saline soils include calcium, sodium, magnesium, chloride, sulfate, bicarbonate, and sometimes others. The proportions and amounts vary widely from place to place.

Salts often accumulate in the soil from the use of saline irrigation waters. Since all irrigation waters contain some salt, salinity may gradually build up even if waters of low salt content are used. This is very apt to occur in soils of poor permeability. The salts added by the irrigation water will not be leached readily through such soils by an excess of applied water. If irrigations are insufficient to provide a water excess, leaching will not occur in any soil. High water tables are a frequent cause of soil salinity, because water evaporates from the soil over a high water table, leaving the dissolved salts behind in the soil.

For most crop plants, the proportions of different salt constituents normally found in saline soils are not important. Growth depression is controlled very largely by the total salt concentration expressed in terms of the osmotic pressure of the soil solution or the electrical conductivity of the saturation extract. Most fruit crops and some trees and woody ornamentals are especially sensitive to chloride and sodium salts (figs. 1 and 2). In addition to the general osmotic growth inhibition, characteristic leaf-burn symptoms develop when chloride or sodium accumulates to harmful levels in the leaves. Such leaf injuries further depress growth and crop yields.

Vegetable, field, and forage crops often accumulate higher levels of chloride and sometimes sodium than fruit crops, but the field, forage, and vegetable crops do not develop the leaf-injury symptoms caused by these ions. Moreover, growth of these crops is not directly impaired by sodium or chloride accumulations in the plants.

What Is the Relative Importance of Specific Ion (Sodium or Chloride) Injury and Osmotic Growth Inhibition?

The relative effects vary widely, depending on the plant species.

Chloride and sodium injury may be the dominant factors in reducing fruit crop yields, or they may be relatively unimportant despite severe leaf-injury symptoms. Growth of grapevines may be only moderately checked by a saline soil solution if chloride salt concentrations are low, but the vines may be completely destroyed at the same salinity if chloride salts predominate. On the other hand, strawberries are just as strikingly subject to leaf burn caused by damaging levels of chloride as grapes. However, strawberry growth is controlled almost entirely by the osmotic pressure of the saline solution, so that growth and yield tend to be equally affected in the presence or absence of chloride-burn symptoms. Most fruit crops show an intermediate reaction; part of the growth inhibition results from the osmotic effect and a more or less equal part from leaf injury caused by chloride or sodium accumulation.

How Much Salinity Can Fruit Crops Tolerate?

Most fruit crops are salt-sensitive; tolerances for a given crop vary primarily because different varieties or rootstocks take up toxic ions at different rates.

Different varieties of most crop plants are so similar in salt tolerance that varietal differences are of little importance. Among the chloride- and sodium-sensitive fruit crops, however, different rootstocks or varieties can take up chloride or sodium at such dissimilar rates that tolerance of a crop may depend greatly on the rootstock or variety.

Another factor that complicates the salt-tolerance picture for fruit crops is their sensitivity to specific salts. The relative abundance of chloride or sodium can be as important as the total salt level.

Data in table 1 on tolerance of citrus and avocado rootstocks to chloride salts are based on research at Weslaco, Tex. The data on other fruits derive from experimental work at the U.S. Salinity Laboratory. The more resistant rootstocks and varieties can tolerate two to three times more chloride in the soil solution than the more sensitive ones, because the resistant ones absorb chloride at much slower rates.

Muskmelons are not specifically sensitive to chloride or sodium. Information is lacking on other fruit crops not listed in table 1. The more tolerant ones—date and olive—are probably not sensitive to chloride; pecans, walnuts, and some other nut trees are known to be sensitive.

In addition to chloride uptake, other factors must be considered in selecting rootstocks for saline areas. Rootstocks that restrict chloride uptake may absorb sodium or boron to a greater degree than others (i.e., Cleopatra mandarin). Such factors as disease and frost resistance must also be taken into account. Ideal rootstocks are yet to be found, but salt resistance will be an important rootstock or varietal characteristic for irrigated areas.

Some annual crops and also many perennial forage crops become more salt tolerant as the plants grow older. Fruit crops, on the contrary, often become more sensitive after 2 or 3 years. Chloride and sodium accumulate more rapidly in the leaves, and leaf burn develops earlier in the season and with increasing severity. This is especially noticeable in stone fruits and grapes. A carryover of accumulated salt in roots and trunks and the reduced growth rate of older plants are probably responsible for the earlier attainment of critical salt contents in the leaves of older plants.

TABLE 1.—*Salt tolerance of fruit-crop varieties and rootstocks and hazardous chloride levels in the saturation extracts*

Crop	Rootstock or variety	Limit of tolerance to chloride in saturation extract
		Milliequivalents per liter
	ROOTSTOCKS	
Citrus	Rangpur lime, Cleopatra mandarin.	25
	Rough lemon, tangelo, sour orange.	15
	Sweet orange, citrange	10
Stone fruit	Marianna	25
	Lovell, Shalil	10
	Yunnan	7
Avocado	West Indian	8
	Mexican	5
	VARIETIES	
Grape	Thompson Seedless, Perlette	25
	Cardinal, Black Rose	10
Berries[1]	Boysenberry	10
	Olallie blackberry	10
	Indian Summer raspberry	5
Strawberry	Lassen	8
	Shasta	5

[1] Data available for single variety of each crop only.

The salt tolerance list in table 2 is based primarily on the sensitivity of fruit crops to osmotic pressure. This factor is important when specific ion injury is kept at a minimum; for instance, (1) when chloride and sodium are not predominant ions, or (2) when rootstocks are used that restrict the uptake of sodium and chloride, or (3) when specific ion injury is unimportant as compared to osmotic inhibition. The EC_e values refer to the electrical conductivity of the saturation extracts of the soil at which yields may begin to decline. If the values in an orchard are similar to those shown in table 2, growth of the plants will be slowed and, as a result, yields may be reduced approximately 10 percent.

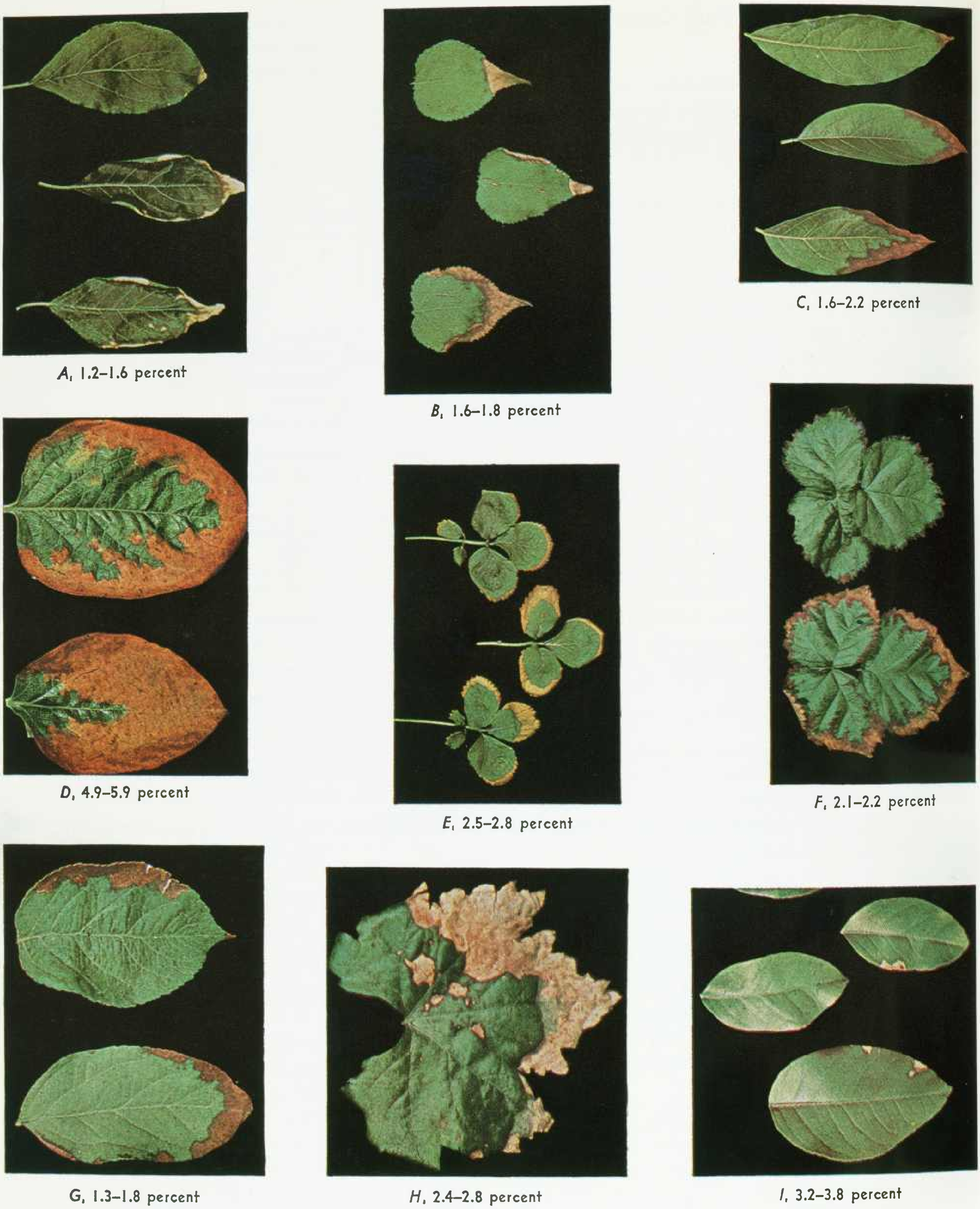
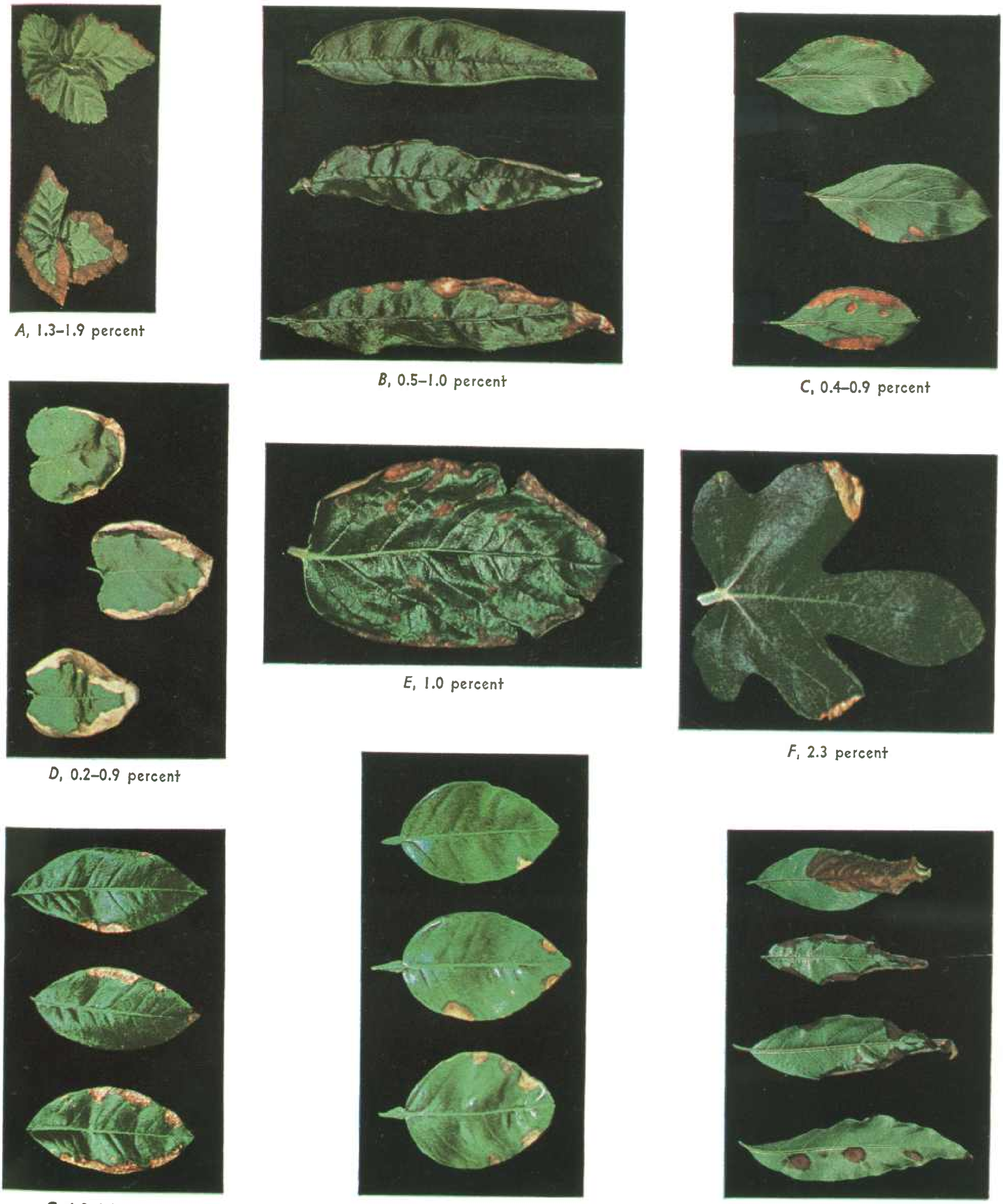


FIGURE 1.—Sensitivity of fruit crops to chloride salts: Progressive tip and marginal burns in plum (*A*), apricot (*B*), avocado (*C*), persimmon (*D*), strawberry (*E*), and boysenberry (*F*); variable burns in apple (*G*) and grape (*H*); and slight bronzing and burn in grapefruit (*I*). Actual chloride contents of these leaves are indicated as percentages of dry leaf weight; injury can, however, occur at lower chloride contents.



A, 1.3–1.9 percent

B, 0.5–1.0 percent

C, 0.4–0.9 percent

D, 0.2–0.9 percent

E, 1.0 percent

F, 2.3 percent

G, 1.2–1.3 percent

H, 3.0–3.1 percent

I, 1.1–1.7 percent

FIGURE 2.—Sensitivity of fruit crops to sodium salts: Progressive tip or marginal burn in boysenberry (*A*), peach (*B*), plum (*C*), and apricot (*D*); marginal and interveinal burn in persimmon (*E*); tipburn of fig (*F*); marginal burns of lemon (G) and grapefruit (*H*); and variable signs in avocado (*I*). Actual sodium contents of these leaves are indicated as percentages of dry leaf weight; injury can, however, occur at lower sodium contents.

Even on the basis of osmotic effects alone, it is apparent that fruit crops tend to be more salt-sensitive than other crop plants (vegetable, field, and forage crops). Sensitive fruit crops include 75 percent of the species listed; sensitive species among other crop plants make up only 5 to 15 percent of the total.[1]

TABLE 2.—*Soil salinities in root zone at which yield reductions become significant*

Crop	Electrical conductivity of saturation extracts (EC_e) at which yields decrease by about 10 percent[1]
	Millimhos per centimeter at 25° C.
Date palm	8
Pomegranate, Fig, Olive	[2] 4-6
Grape	4
Muskmelon	3.5
Orange, grapefruit, lemon[3]	3-2.5
Apple, pear	2.5
Plum, prune, peach, apricot, almond.	2.5
Boysenberry, blackberry, raspberry.[3]	2.5-1.5
Avocado	2
Strawberry	1.5

[1] In gypsiferous soils, EC_e readings for given soil salinities are about 2 millimhos per centimeter higher than for nongypsiferous soils. Date palm would be affected at 10 millimhos per centimeter, grapes at 6 millimhos per centimeter, etc., on gypsiferous soils.

[2] Estimate.

[3] Lemon is more sensitive than orange and grapefruit; raspberry is more sensitive than boysenberry and blackberry.

How Does Salinity Affect Fruit Quality?

Quality is generally impaired by salinity, but some beneficial effects can occur.

Even in the absence of appreciable leaf burn, the checking of growth by salinity may still affect quality by decreasing fruit size. Muskmelon size is strongly affected. However, for the more sensitive fruit crops, salinity levels for satisfactory growth are so narrowly restricted that the effects on fruit size are minimized.

Extensive leaf burn exposes fruit to the sun, and sunscald can markedly lower fruit quality. This is an important factor for grapes.

The check on vegetative growth may result in increased sugar content of fruit and improved flavor. Muskmelons show this effect but at the cost of smaller fruit and decreased yields. Again, because salinity must be kept at low levels, such effects on fruit quality are less pronounced for the more sensitive fruit crops.

Muskmelons and some other melons and fleshy fruits grown on saline soils are markedly softer and juicier at the normal harvest stage than fruit from nonsaline soils. The softer fruit may not store or ship as well as the firmer fruit.

How Can One Confirm Suspected Salt Injury to Fruit Crops?

Leaf analysis is used to confirm toxic salt accumulations. Soil analyses indicate excessive soil salinity.

Marginal and tipburn of fruit-crop leaves are usually strong indicators of chloride or sodium toxicity (see figs. 1 and 2). Similar symptoms may, in some cases, be caused by other conditions such as drought or boron toxicity.[2] If affected leaves are found to contain more than 0.2 percent sodium or 0.5 percent chloride, the leaf injury can usually be attributed to sodium or chloride toxicity. Leaf analysis is, therefore, extremely useful in diagnosing salt injury to fruit crops.

Leaf burn is generally more severe after hot, dry weather than during cool, cloudy periods. Foliar analysis may reveal potentially harmful sodium or chloride accumulations before leaf symptoms become apparent.

Some of the more sensitive fruit crops—citrus,

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

BERNSTEIN, LEON. THE SALT TOLERANCE OF VEGETABLE CROPS IN THE WEST. U.S. Dept. Agr., Agr. Inform. Bul. 205, 5 pp. 1959.

BERNSTEIN, LEON. THE SALT TOLERANCE OF FIELD CROPS. U.S. Dept. Agr., Agr. Inform. Bul. 217, 6 pp. 1959.

[2] WILCOX, L. V. BORON INJURY TO PLANTS. U.S. Dept. Agr., Agr. Inform. Bul. 211, 7 pp. 1959.

stone and pome fruits, and avocados—may absorb sufficient sodium to cause injury from soil that would be classified as nonsaline and nonsodic. Although 15 percent exchangeable sodium is usually set as the approximate lower limit for sodic soils, as little as 5 to 10 percent exchangeable sodium may cause harmful sodium accumulation in citrus, avocado, and stone fruit trees.

Stone fruit trees normally translocate very little sodium into the leaves; however, they may, under some unfavorable growing conditions as yet poorly understood, begin to accumulate high levels of sodium in the leaves. Severe sodium scorch of the leaves and ultimate death of the trees may result, even though soluble and exchangeable sodium occur in only low concentrations in the soil. The exchangeable sodium percentage may be only 2 to 3 percent and the EC_e only 1 to 2 millimhos per centimeter.

Severe growth and yield reduction may occur in the absence of harmful chloride or sodium accumulations. Soil samples taken from the root zone of the crop can be analyzed for soluble salt content by determining the electrical conductivity of the saturation extract. If the EC_e approximates or exceeds the value given in table 2 for the crop in question, salt damage to the crop is probably occurring.

Apart from leaf injury and stunted growth that may be apparent only if normally growing plants are available for comparison, salinity causes no distinctive symptoms in most fruit crops. Apricots, however, do develop curling of the leaves that suggests water stress. If this symptom occurs when soil moisture is adequate or if it persists even after irrigation, salinity is probably responsible. Root injury may also cause similar leaf curl symptoms.

How Does Sprinkling Affect Fruit Crops?

If leaves are wetted by sprinkling, rapid uptake of chloride or sodium by the leaves may cause severe leaf burn.

Ordinarily, the sodium and chloride found in leaves are absorbed by the roots and transported into the leaves. But leaves may absorb salt directly if they are wetted by sprinkling or if sea spray is carried inland by the wind. Irrigation waters that contain as little as 3 milliequivalents per liter of sodium or chloride (equivalent to about 70 p.p.m. sodium or 100 p.p.m. chloride in the water) may be injurious if applied as leaf-wetting sprays. Such waters may cause no salinity problem when applied to the soil. Some fruit crops absorb salt through the leaves about 100 times faster than through the roots. Peaches, plums, apricots, almonds, and citrus trees accumulate salt very rapidly in this way. Strawberries and avocados, on the other hand, absorb relatively little salt through the leaves and may be safely sprinkled.

Windblown sprays are particularly hazardous, because salt accumulates on the leaves and is not removed by drip or runoff. Very high salt concentrations in such cases can damage any crop, whether the salt is absorbed or not. Intermittent wetting of leaves, as by rotating sprinkler heads, permits some evaporation of the water from the leaves and increases its salt concentration. The higher the salt concentration, the more rapid is the absorption of salt. Salt absorption by leaves is about twice as rapid during midday as during evening sprinkling.

Sprinkling, however, can prevent the salt accumulation in the soil that occurs in the ridges or unirrigated middles of furrow-irrigated plantings. Salt, including soluble fertilizer salts, may reach very high concentrations in the ridges of furrow-irrigated fields. Subsequent rainfall washes the salt into the root zone, and this can cause severe injury. Low-head sprinklers that do not wet the leaves can achieve all the benefits of sprinkler irrigation without the hazards of salt absorption by fruit crop leaves.

How Does Irrigation Frequency Affect Salt Injury?

Infrequent irrigation aggravates salinity effects.

After an irrigation, crops absorb water from the soil but take up very little of the salt dissolved in this water. Some water is also lost by direct evaporation from the soil. As a result, the soil solution becomes progressively more concentrated. If the period between irrigations is lengthened, salt concentrations will increase to higher levels and salt damage will be greater. Crops are generally damaged less by given levels of soil salinity if irrigations are more frequent. It is desirable to irrigate plantings on saline soils at a lower moisture tension (or a higher moisture content) than if the same fields were nonsaline. In terms of tensiometer (moisture meter) readings, a saline field should be irrigated at one-fifth- to one-third-bar tension instead of one-half- to one-bar tension or higher, as recommended for nonsaline soils. (one-bar tension is approximately a full-scale reading of the moisture meter.)

How Much Water Must Be Applied To Prevent Excess Salinity From Developing?

The amount of excess water required depends on the quality of the water, the salt tolerance of the crop, and its consumptive water use.

If only enough water is added in each irrigation to replace that which has been lost from the soil by evaporation and transpiration, the salt added with the water will accumulate continuously to higher and higher levels in the root zone. An excess of water must be added either with each irrigation or periodically, to move salts out of the root zone. The salt tolerance of the crop determines the maximum permissible soil salinity. This is generally about 1½ times greater than the salinity level at which small decreases in yield of the crop occur. For the sensitive fruit crops, the maximum salinity will therefore be 3 to 6 millimhos per centimeter (EC_e) at the bottom of the root zone, since small yield decreases occur at 2 to 4 millimhos per centimeter.

The fraction of total applied water needed to leach the salts in the root zone below the level of damage to the crop is called the leaching requirement (LR). It can be estimated by dividing the electrical conductivity of the irrigation water by the electrical conductivity of the drainage water, or the maximum permissible salinity as defined above.

Instead of electrical conductivities, one may use chloride concentrations if chloride is more critical than total salinity for the crop and water in question. Then the leaching requirement can be estimated by dividing the chloride concentration in the irrigation water by the maximum permissible chloride concentration in the drainage water. (See table 1.)

Thus, if a 1-millimho-per-centimeter water is used to irrigate grapes with a maximum tolerance (EC_e) of 6 millimhos, the leaching requirement is one-sixth, or 17 percent. This means that one-sixth of the water penetrating the soil must carry salt below the root zone. This may occur more or less regularly with each irrigation, or periodically as extra-heavy irrigations are applied. Obviously, internal drainage must be adequate to permit this downward displacement of soil solution.

The total depth of water (D) required for irrigating a crop can be calculated if its consumptive use (CU) is known by the following equation:

$$D = \frac{CU}{1 - LR}$$

Thus, if a crop has a CU of 40 inches of water and if the leaching requirement is one-fifth, D will be 50 inches. Ten inches of water, or one-fifth of the total depth of water applied to the soil, will be available for leaching. The resulting leachate will be five times as concentrated as the applied water.

How Do Fertilization and Management Practices Affect Salt Injury?

Good management and fertilization can decrease harmful salinity effects by promoting vigorous growth.

Poor growth may result from inadequate fertilization or failure to irrigate for long periods during or after harvest. Whatever the cause of poor growth, salt accumulation in the leaves and leaf burn will generally increase. Any management practices that will encourage better growth of the fruit crops can do much to overcome damage caused by salinity.

Summary

1. Most fruit crops are sensitive to salinity. In many fruit crops, leaf burns develop when chloride or sodium accumulates in the leaves. Leaf analysis as well as soil analysis is useful in diagnosing salt injury to fruit crops.
2. Different rootstocks and varieties absorb sodium and chloride at greatly different rates, so that some varieties and rootstocks are much more salt-resistant than others.
3. Citrus and stone fruit crops absorb sodium and chloride rapidly through the leaves. Wetting leaves by sprinkling can be particularly injurious to such crops.
4. Frequent irrigation prevents salt concentrations from building up in saline soils between irrigations. Excess water must be applied regularly or at intervals to assure downward movement of salt below the root zone. Good drainage is essential.
5. Good management and fertilization promote vigorous growth that dilutes the salt in the plant. Weak growth will result in higher salt concentrations in the plant and greater leaf damage.

Washington, D.C. Issued August 1965

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D. C. 20402 Price 15 cents

☆ U. S. GOVERNMENT PRINTING OFFICE: 1965—760-292