Chapter 11

SALINITY AND FRUITING

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INTRODUCTION

Salinity may be defined simply as the presence of excessive concentrations of soluble salts (U.S. Salinity Lab Staff, 1954). Soils are regarded as saline if they contain soluble salts in such quantities that they interfere with the growth of most crop plants. Chloride, sulfate and bicarbonate salts of sodium, calcium and magnesium contribute in varying degrees to soil and water salinity.

Millions of hectares of land throughout the world are too saline to produce economic crop yields, and more land becomes nonproductive each year because of salt accumulation. Salinity problems in agriculture are usually confined to arid and semi-arid regions where rainfall is not sufficient to transport salts from the plant root zone. Salinity is a hazard on about half of the irrigated area of the western United States (Wadleigh, 1968) and crop production is limited by salinity on about 25 percent of this land (Thorne and Peterson, 1954; Bower and Fireman, 1957; Wadleigh, 1963). Soil salinity problems may also occur on non-irrigated croplands and rangelands. For example, Carter *et al.* (1964) reported that approximately 25 percent of the non-irrigated land in the lower Rio Grande valley of Texas is highly saline. The saline soils are interspersed among non-saline soils, so that farmers must plant and cultivate saline areas along with non-saline areas. Thus, farmers may actually harvest only about 75 percent of the land area they farm.

Salinity of irrigation water is also a problem and is becoming an increasingly serious one as water of less and less desirable quality is exploited for irrigation and as greater intensity of water use leads to degradation. Similarly, river waters have become more highly regulated. Water evaporating from reservoirs concentrates the salts, and new irrigation projects aggravate the salinity problem for downstream users.

Several of the major cotton producing regions of the United States are located in the semiarid and arid southwestern and western states where saline soils and irrigation waters are common. In these regions, salinity impacts directly upon cotton production by reducing yield and requiring the use of costly management practices to maintain productivity.

GENERAL PLANT RESPONSE TO SALINITY

The primary salinity factors influencing plant growth are the kind and concentration of salts in the soil solution (or irrigation water). Most plants respond to salinity as a function of the total salt concentration or osmotic potential of soil water without regard to salt species present (Maas and Hoffman, 1977). Where ratios of the predominate soluble ions are extreme, specific ion toxicities may occur. Some herbaceous plants and most woody species are susceptible to specific ion toxicities. In some cases, salinity induces nutritional imbalances or deficiencies causing decreased growth and plant injury for which osmotic effects alone cannot account.

Although salinity affects plants in many ways physiologically, overt injury symptoms seldom occur except under extreme salination (Mass and Hoffman, 1977). Salt-affected plants usually appear normal, although they are stunted with plant parts such as leaves, stems and fruits usually smaller than normal, and may have darker green leaves which, in some cases, are thicker and more succulent. The most common salinity effect is a general stunting of plant growth. As salt concentrations increase above a threshold level, both the growth rate and ultimate size of most plant species progressively decrease. Not all plant parts are affected equally. Top growth is often suppressed more than root growth. Salinity may also increase the leaf:stem ratio and may affect vegetative growth more than yield of seed or fiber. 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.

COTTON TOLERANCE TO SALINITY

The only agronomically important criterion for establishing salt tolerances of crops is the effects on economic yield. Salinity for the purposes of establishing crop tolerance is conveniently measured by determining the electrical conductivity (EC) in millimhos/cm at 25C of irrigation drainage water or soil extract (U.S. Salinity Lab Staff, 1954). One millimho is the approximate equivalent of 640 ppm salt. Four divisions for classifying salinity tolerance of crops have been established based upon the electrical conductivity of the soil extract (EC_e) and the effect of salinity upon crop yield. These classifications are sensitive, moderately sensitive, moderately tolerant and tolerant. Cotton is classified as a salt tolerant crop (U.S. Salinity Lab Staff, 1954; Bernstein, 1955; Ayers and Westcot, 1977). A threshold salinity level at which initial yield decline has been observed is 7.7 millimhos (EC_e)/cm with a 50 percent reduction in yield observed at an EC_e of 17.0 millimhos (Ayers and Westcot, 1977).

The range of genetic variability to salt tolerance among species of *Gossypium* is apparently unknown. Among upland cotton varieties (*G. hirsutum*) tested by the

U.S. Salinity Laboratory, according to one report (Bernstein, 1955), most had similar salt tolerance with the exception of Hopi-Acala 46-124 and Arizona 124-68 which tended to tolerate higher salinities than a group characterized by Acala 4-42. From another study at the U.S. Salinity Laboratory, Hayward and Wadleigh (1949) reported a wide variation in relative salt tolerance among 12 varieties evaluated in sand culture over a 3-year period. The American-Egyptian (*G. barbadense* L.) varieties, SXP, Amsak and Sakel, and the upland varieties, Acala 1517 and Acala P-18, had consistently good salt tolerance. Stoneville strains also produced good relative yields on saline cultures but always displayed noticeable symptoms of salt toxicity. Other strains evaluated—Coker 100-6, Deltapine 14 and Delfos 9252—did not show any distinctive degree of salinity tolerance. Hayward and Wadleigh (1949) also stated that the long staple Egyptian types were more tolerant to salt than the upland types.

In a more recent screening test of seven upland varieties, genotypic differences in salt tolerance were also observed (Lauchli *et al.*, 1981). Differences in tolerance at various growth stages were also readily apparent as Paymaster 303 and Acala SJ-2 were relatively salt tolerant during germination and seedling emergence, while Acala SJ-5, Coker 310, Stoneville 825 and Tamcot SP37H displayed poor germination and low emergence at high salinities. At later stages of vegetative growth, Acala SJ-2 and Stoneville 825 were two of the most tolerant varieties with Deltapine 61 and Coker 310 showing the least tolerance.

SPECIFIC EFFECTS OF SALINITY ON COTTON

Very little data appear in the literature on the specific effects of salinity on the fruiting of cotton. Some work has apparently been done with reference to yield and salt tolerance of specific varieties which is not readily accessible in the literature.

In most crops studied, fruit yields tend to parallel declining vegetative growth as salinity increases. In studies with cotton, exceptions have been noted, however. Bernstein and Hayward (1958) reported a marked decline in vegetative growth and vigor of cotton in response to increasing levels of salinity with little effect on yield of seed cotton. Ehlig (1969) observed that salinity reduced cotton plant height, number of main stem nodes and internode length but did not always reduce the number of flowers. These reductions in vegetative growth without corresponding reductions in reproductive growth undoubtedly occurred at salinity levels lower than the threshold level listed by Ayers and Westcot (1977) and Maas and Hoffman (1977) for the initial yield decline in cotton of 7.7 mmhos/cm (EC_e). The salinity threshold for the initial yield reduction in cotton probably depends on several factors, however, as Thomas (1980) observed an initial yield decline on soils with mean EC_e's in the range of 3 to 5 mmhos/cm. This discrepancy is apparently due to the differences in the experimental conditions under which the values were obtained (Maas and Hoffman, 1977; Thomas, 1980) but also may reflect differences in the level of salt tolerance of the experimental plant material. The level of salinity at which yield reduction occurs may be influenced by other environmental conditions such as temperature (Magistad *et al.*, 1943) and humidity (Nieman and Paulsen, 1967) as well as the composition of solutes in the soil solution (Callahan and Joham, 1974).

Decreases in fruit yield associated with salinity are usually the result of decreases in both fruit number and size (Bernstein and Hayward, 1958). Also, as salinity has a retarding effect on vegetative growth, it would be expected to delay the onset of flowering. But by reducing vegetative growth in a crop with an indeterminate fruiting habit, such as cotton, salinity may increase earliness of crop maturity, thereby hastening final harvest (Bernstein and Hayward, 1958; see also Chapter 7).

PHYSIOLOGICAL FUNCTIONS OF COTTON INFLUENCED BY SALINITY

Certain physiological functions of cotton are affected by salinity. The effects of salinity on these functions may indirectly affect fruiting of cotton. Transpiration, and thus water requirement, of cotton decreased progressively with increasing concentrations of NaCl, $NaNO_3$, KCl, KNO_3, $CaCl_2$ and $Ca(NO_3)_2$ salts in the soil (Meyer, 1931; Hoffman *et al.*, 1971).

The photosynthetic functions of leaves is altered in several ways when plants are grown in saline conditions. Boyer (1965) observed a 25 percent reduction in both photosynthesis and respiration in cotton grown at NaCl levels corresponding to -8.5 bars. Resistance to CO_2 diffusion did not increase at high solute concentrations. On the other hand, Gale *et al.* (1967) could not repeat Boyer's results. They concluded from their data that salinization to -4.5 bars increased stomatal resistance to CO_2 and water but that the major reason that salinity reduced pohotosynthesis was its effect on the light reactions of the process.

Hoffman and Phene (1971) observed a decrease in both photosynthesis and transpiration when salinity was increased. This would indicate an effect of the salinity on stomatal aperture. Their observation that salinized plants had lower water-use-efficiency would indicate a greater effect of salinity on CO_2 uptake than on transpiration.

The work of Longstreth and Nobel (1979) showed that salinity can increase both stomatal and mesophyll resistance in cotton leaves and that the effect is reversible. They found that cotton leaves grown in saline medium had more succulent leaves. That is, the ratio of mesophyll cell area to leaf area (A^{mes}/A) was greater under saline conditions. This increase in A^{mes} partially compensated for the great decrease in CO_2 uptake per cell. Thus, when salinity was less than 0.1 molal NaCl, no change in mesophyll resistance was observed. Therefore, the conditions of the experiment and the length of time the plants had for compensation might be expected to produce differing results.

SUMMARY

The physiology of cotton response and adaptation to salinity is relatively unexplored. The high salt tolerance of most varieties of cotton evaluated suggests that this factor in itself may be the reason why the physiology of salt adaptation in cotton and the specific effects of salinity on cotton functions have not been studied more thoroughly. Another factor involved is that much of the research effort directed toward salinity problems has been expended in manipulating the environment—the soil and water—to suit the crop. However, reclamation and drainage projects are exceedingly expensive operations in terms of dollars, energy and good water. As competition for water increases from the non-agricultural sectors of the economy, pressure will increase on the agricultural community to increase the efficiency of water use and exploit lower quality waters for agricultural purposes. And, as the world population grows, the demand for increased agricultural production will force us into utilizing less desirable land and water resources in an effort to increase production. The impetus for selecting and breeding salt-tolerant crops is already upon us. Development of salt-tolerant crops should be reinforced by physiological research into the nature of salt tolerance in plants. Cotton as well as other salt tolerant crops are prime candidates for such breeding programs; and cotton, undoubtedly, will be one of the crops selected for use under moderate levels of salinity.