CROP SALT TOLERANCE - CURRENT ASSESSMENT

E. V. Maas and G. J. Hoffman

U. S. Salinity Laboratory

Agricultural Research Service

U. S. Department of Agriculture

P. O Box 672

Riverside, California 92502

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E. V. Maas[1] and G. J. Hoffman[2], M. ASCE

INTRODUCTION

Crop salt tolerance has usually been expressed as the yield decrease expected for a given level of soluble salts in the root medium as compared with yields under nonsaline conditions (20, 152, 7, 26, 28, 61). However, salt tolerance is a relative value based upon cultural conditions under which the crop was grown. Salt tolerance lists published by the U.S. Salinity Laboratory (152, 7, 26, 28) represent relative tolerances when crops are grown under conditions simulating recommended cultural and management practices for commercial production. Absolute tolerances that reflect predictable inherent physiological responses by plants cannot be determined because many interactions among plant, soil, water, and environmental factors influence the plant's ability to tolerate salt. Useful quantitative salt tolerance data must account for these interacting factors and be based upon appropriate measures of soil salinity and plant response.

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[1]Supervisory Plant Physiologist, U. S. Salinity Laboratory, Agricultural Research Service, USDA, P. O. Box 672, Riverside, California 92502.

[2]Agricultural Engineer, U. S. Salinity Laboratory, Agricultural Research Service, USDA, P. O. Box 672, Riverside, California 92502.

A literature review reveals that a myriad of experimental procedures have been used for determining salt tolerance. Experiments have been conducted in soil, sand, and water cultures; in fields, small plots, greenhouses, and growth chambers; and under nearly every conceivable environmental condition. Salination methods vary as do ways of measuring and reporting salinity levels in the root medium. Likewise, plant response to salinity has been measured in several ways and at various stages of growth and development. In many experiments, important variables were either not controlled or not measured or reported.

In spite of these problems, we have attempted to compile and normalize all available salt tolerance data from the past 30 years to present our best current assessment of the salt tolerance of agricultural crops. Included are only those data correlating plant response to the total soluble salts in the root medium. Sodic soil conditions, specific ion toxicities, and nutritional effects are not considered here, but, if present, they must be taken into account.

PLANT RESPONSE TO SALINITY

Although salinity affects plants in many ways physiologically, overt injury symptoms seldom occur except under extreme salination. Salt-affected plants usually appear normal, although they are stunted and may have darker green leaves which, in some cases, are thicker and more succulent. Woody species are an exception since toxic accumulations of Cl or Na may cause leaf burn, necrosis, and defoliation. Most herbaceous plants do not exhibit leaf injury symptoms even though some accumulate Cl and Na to levels as high as those causing injury in woody species. Occasionally, nutritional imbalances caused by salinity produce specific nutrient-deficiency symptoms.

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, however, and any correlation between growth response and soil salinity must take this into account. Top growth is often suppressed more than root growth (47, 64, 120, 17). Salinity also increases the leaf-stem ratio of alfalfa, thereby influencing forage quality (94).

The only agronomically significant criterion for establishing salt tolerance is the commercial crop yield. Too often vegetative growth response to salinity is not a reliable guide for predicting fruit or seed production. Grain yields of rice (131) and corn (102) may be greatly reduced without appreciably affecting straw yield. With some other crops, e.g., barley, wheat, cotton and some tolerant grasses, seed or fiber production are decreased much less than vegetative growth (15, unpublished USSL data). For root crops, storage-root yields may be decreased much more than that of tops or fibrous roots (15, 96).

Although most plants respond to salinity as a function of the total osmotic potential of soil water without regard to the salt species present (24), some herbaceous plants and most woody species are susceptible to specific ion toxicities. Because of these toxicities, yield losses of fruits and nuts are generally greater than those predicted from osmotic effects alone. Detailed data on Cl and Na tolerances of these crops are not available but tolerable levels causing yield reductions of 10% or less are published (27, 132).

In some cases, salinity induces nutritional imbalances or deficiencies causing decreased growth and plant injury for which osmotic effects alone cannot account (25, 44). Blossom-end rot of tomato and pepper (64, 78), blackheart of celery (77), and internal browning of lettuce (25) are all symptoms of Ca deficiency which may occur in saline soils characterized by high sulfate and low Ca levels. Magnesium deficiencies, also caused by high sulfate levels, have been observed on several varieties of table grapes (65).

Obviously, the relationship between osmotic potential of the soil solution and crop yield is invalid under conditions in which specific ion effects are significant. Accordingly, corrections must be made for the additional detrimental effects.

METHODS OF SALINITY MEASUREMENT

The parameter chosen to relate salinity to plant tolerance must correlate closely with plant growth and yield. Without specific ion effects, growth reduction is primarily related to the osmotic potential of the soil solution in the root zone (44). Osmotic potential can be measured directly by freezing-point depression, vapor-pressure osmometers, or thermocouple psychrometers, as is often done for sand and solution culture studies; but, in general, these methods have not been adopted for soils.

The most common method of measuring soil salinity is to determine the electrical conductivity of saturation extracts (EC_e) from the active root zone. Electrical conductivity (EC) is directly related to the concentration of soluble salts in the soil solution and within limits to osmotic potential (ψ_o) by the relationship, $\psi_o = -0.36$ EC. Using EC_e was recommended because the saturation percentage is easily and reproducibly determined in the laboratory and is related to the field-moisture range of soils varying widely in texture (152). For many soils, the soluble salt concentration of the soil solution at field capacity is about twice that at saturation. Nevertheless, salinity measurements obviously would be more reliable if made on soil solutions in the field-moisture range.

Some recent developments in instrumentation now permit direct determinations of electrical conductivity of soil water (EC_{sw}). Two devices that allow rapid, reliable and non-destructive measurements are salinity sensors and four-electrode probes. Salinity sensors permit *in situ* measurement of EC_{sw} at a given location in a soil profile (143, 129). They function throughout the range of soil matric potential normally encountered in irrigated fields and respond adequately to salinity changes in the soil solution typically found in the field (157). The four-electrode probe can also be used for assessing *in situ* soil salinity but requires a knowledge of water content, temperature, soil texture and cation-exchange-capacity. Rhoades and Ingvalson (142) suggested that the relationship between soil conductivity and soil salinity be determined for each soil type at a known water content and soil temperature. Once this relationship is established, no further soil samples or laboratory analyses are required. In field practice, they recommend measuring soil conductivity just after an irrigation when water content is reasonably reproducible. The method is simple, rapid, and can be used for diagnosis, survey, and management practices (141).

As important as measuring the primary parameter to which the plant responds, is knowing where and when to make the measurement.. Salt distribution in the soil usually varies in both space and time. Depending upon leaching fraction, salinity profiles may be rather uniform and change relatively little with depth or they may be highly nonuniform with salinities varying from concentrations approximately that of the irrigation water near the soil surface to concentrations many times higher at the bottom of the root zone. As a result of evapotranspiration and drainage, the salt concentration also changes with time between irrigations; consequently, irrigation frequency influences the magnitude of these changes. To minimize the ambiguity of interpreting results from nonuniform salinity profiles the salt tolerance data derived at this Laboratory (152, 26, 28) were obtained from experiments in artificially salinized field plots where salinity was maintained essentially uniform with depth throughout the root zone by irrigating with different saline waters at high leaching fractions.

Applying these data to field conditions, where salinity distribution is neither uniform nor constant, requires knowledge of plant response to salinity that varies with time and depth. Several studies support the hypothesis that plants respond to the mean salinity of the root zone (146, 147, 53, 54, 106). Ingvalson, Rhoades, and Page (98) found that alfalfa yields correlated better with time-integrated EC_{sw} than with the mean EC_e. Others studies indicate that the effective salinity level must be weighted in favor of the least saline zone. Lunin and Gallatin (113) found that salination of up to two-thirds of the root zone with synthetic sea water had little effect on corn and tomato growth. Water uptake increased from nonsaline zones and decreased as salinity in saline zones increased. In another zonal salination experiment, Bingham and Garber (50) reported similar results for corn salinized with NaCl and concluded that plants can tolerate excessive salinity levels if an adequate part of the root zone is relatively salt free.

Recently, Bernstein and Francois (41), in a comprehensive leaching-requirement study, found that alfalfa responded primarily to a weighted-mean salinity based upon the amount of water absorbed with depth in the root zone. Because water uptake is inversely related to salt concentration, more water is absorbed from the upper root zone and consequently, the weighted-mean salinity is influenced far more by the concentration of the irrigation water than by the higher concentration of the drainage water.

If the response of all plants is governed primarily by the salinity of the irrigation water rather than the average soil salinity, salt tolerance data obtained from uniform salinity profiles could be applied directly to nonuniform conditions by using soil water salinities measured in the zones of maximum water uptake.

FACTORS INFLUENCING SALT TOLERANCE

Perhaps the most difficult task in assessing crop salt tolerance is accounting for the many factors that may influence the plant's response to salinity. Although the following list presents the salt tolerance of many crops as a simple function of EC_e, the relationship does not always hold. Salt tolerance depends upon many plant, soil, water and environmental variables. Hopefully, a discussion of these interacting variables will caution both those using these data and those conducting salt tolerance investigations.

Plant Factors

Stage of Growth. Salinity affects plants at all stages of development and, for some crops, sensitivity varies from one growth stage to the next. Cereal crops seem particularly variable. Several studies show that rice is tolerant during germination, becomes very sensitive during early seedling growth, and then becomes increasingly more tolerant with maturation (134, 131, 133, 100). Some disagreement exists as to the sensitivity of rice during the flowering stage; Pearson and Bernstein (134) found that rice becomes sensitive again during pollination and fertilization, whereas Kaddah et al. (104, 103) did not. Barley, wheat, and corn are also more sensitive to salinity during emergence and early seedling growth than during germination and later stages of growth and grain development (15, 14, 102). In contrast, sugar beet and safflower are relatively sensitive during germination (18, 71, 70). Soybean tolerance may increase or decrease from germination to later growth depending upon variety (2). Of course, separating effects due to growth stage from those due to duration of salination is important. The data of Lunin, Gallatin and Batchelder (114), Kaddah and Fakhry (101), Kaddah and Ghowail (102) and Meiri and Poljakoff-Mayber (120) showed that plant response was directly related to duration of exposure to salinity. Most USSL salt tolerance data were obtained from salinity treatments imposed after seedlings were established in nonsaline plots and do not necessarily apply to germination and early seedling stages.

Varieties and Rootstocks. Varietal differences, while not common, must be considered in evaluating crop salt tolerance. In studies conducted over the past 30 years at this Laboratory (152, 26, 28), significant varietal differences were found for bermudagrass (see also (158)), bromegrass, and birdsfoot trefoil. Recently, varietal differences among several other crops have been reported by other investigators. The tolerance of rice varieties varies widely according to Akbar, Yabuno, and Nakao (5) and Datta (60). Youngner, Lunt and Nudge (159) found substantial differences among varieties of creeping bentgrass in their response to saline nutrient solutions. Variation may also exist among cultivars of barley (79) and wheat (151). Although most known varietal differences occur among species within the grass family (Gramineae), some variation has been noted among the legumes (Leguminosae). Besides birdsfoot trefoil, varieties of soybean (2) and of berseem clover (121) respond differently to salinity. Varieties of many crops today are developed from a much more diverse genetic base than in the past and this may lead to greater variability.

Rootstock differences are an important factor in the salt tolerance of fruit tree and vine crops. Fruit crops are not only sensitive to salinity *per se* but are particularly susceptible to toxic effects of Na and Cl. Varieties and rootstocks that differ in the absorption and transport of these ions have different salinity tolerances. Cooper (58, 59) found that the salt tolerance of avocado, grapefruit, and orange is closely related to the Cl accumulation properties of the rootstocks. Similar effects of rootstocks on salt accumulation and tolerance have been reported for stone-fruit trees (35). Large differences in the salt tolerance of grape varieties have been linked with rootstock effects on Cl accumulation (65, 36, 81, 145).

Soil Factors

Fertility. Apparent salt tolerance may vary with soil fertility. The types of salinity-fertility interactions affecting interpretations of salt tolerance data have been illustrated by Bernstein, Francois, and Clark (43). Crops grown on infertile soils generally have abnormally high apparent salt tolerance as compared with crops grown on fertile soils because yields on nonsaline soil are severely limited by inadequate fertility (139, 140, 111). Because salinity is not the limiting variable governing growth, the data are of limited value. Obviously, proper fertilization would increase absolute yields even though apparent relative salt tolerance is decreased. Salt tolerance data may be desired for suboptimal conditions, however, where fertilizers are either uneconomical or unavailable.

Published lists of crop salt tolerance based on data from this Laboratory (152, 7, 26, 28) were obtained under optimum fertility for nonsaline conditions. Unless salinity causes specific nutritional imbalances, additional fertilization generally has little effect or reduces salt tolerance. Apparent decreases in salt tolerance with excess N applications have been reported for corn and cotton (105), rice and wheat (127), wheat (110), and spinach (109). No significant change in relative salt tolerance was found for bean (112) or millet, berseem clover, and corn (140, 138), when excess N was applied. Bernstein *et al.* (43) concluded from sand culture studies that high N levels do not increase the salt tolerance of wheat, barley, corn, or six vegetable crops (garden beet, broccoli, cabbage, carrot, lettuce, and onion).

Rarely, if ever, are P levels excessive in soil, even with heavy applications because P is adsorbed or precipitated in the soil. High P levels in sand or water cultures, however, may aggravate salt injury and decrease salt tolerance. Bernstein et al. (43) reported a decrease in the salt tolerance of corn grown in sand cultures at soluble P levels of 16 and 64 mg/liter as compared with 1.6 mg/liter. The high P level (16 to 24 mg/liter) in the water culture study of Torres and Bingham (151) may account for the decreased salt tolerance they reported for wheat. In soil, most studies have verified that excess P applications have no effect on salt tolerance (69, 110, 112, 105). Ravikovitch and coworkers (138, 139, 140), however, observed that high P levels can influence salt tolerance for some crops.

Fewer studies have been conducted on the influence of excessive K levels on salt tolerance, but high K levels do not seem to have a significant effect (43, 111, 139).

Soil water and aeration. Immediately after irrigation, soil water content is maximum and soluble salt concentration is minimal. As water is lost from the soil by evaporation and crop transpiration, most of the salts are excluded by the plant and left behind in a reduced volume of soil water. The drier the soil becomes before the next irrigation, the higher the average salt concentration for the irrigation cycle. Since plants tend to respond to the sum of the osmotic potential of the soil solution and the soil matric potential, the more saline the soil water the more frequent the irrigations must be to minimize plant water stress. Also, since osmotic potential is such a large factor in saline soils, the available water in a given soil generally decreases as salinity increases. Frequent irrigation minimizes the influence of soil matric potential in salt tolerance studies. Matric potential, of course, is not a factor in properly irrigated water- and sand-culture studies. However, extrapolating the data obtained under steady salinity conditions in these cultures to fluctuating soil water contents in the field can be a major source of error.

Another problem in evaluating salt tolerance studies conducted on field soils may develop from a shallow water table. Deep-rooted plants may extract water from a shallow water table and, depending upon the quality of water, plants may respond much differently than expected from salinity levels in the soil profile.

Excessive irrigation can cause poor soil aeration, particularly in fine-textured soils. Low oxygen levels have interacted with salinity to affect shoot growth of tomato (10) and wheat germination (3).

Environmental Factors

Climate may significantly influence plant response to salinity. Temperature, atmospheric humidity, and air pollution have markedly influenced salt tolerance. Many crops seem less salt-tolerant when grown under hot, dry conditions than under cool, humid ones. On the other hand, air pollution increases the apparent salt tolerance of oxidant sensitive crops. Since not all crops are affected equally, these environmental factors must be considered when assessing salt tolerance.

Magistad and coworkers (118) found that relative yields of alfalfa, bean, beet, carrot, cotton, onion, squash, and tomato were depressed more in warm than in cool climates. Ahi and Powers (4) found similar results for alfalfa, strawberry clover, and saltgrass. The salt tolerance of bean grown in a cool climate is significantly higher than when grown under hot conditions (95).

High atmospheric humidity tends to increase the salt tolerance of some crops (95, 96, 97). High humidity generally benefits salt sensitive crops more than tolerant crops because increases in salt tolerance result in greater yield increases.

A strong interaction between the effects of ozone, a major air pollutant, and salinity has been found in pinto bean, garden beet, and alfalfa. At ozone concentrations often prevalent in several agricultural areas, alfalfa yields may be increased by maintaining moderate but not detrimental salinity levels (94). Salinity also reduced ozone damage in pinto bean and garden beet, but effects are beneficial at salinity and ozone levels too high for economical production (93, 126). These initial results indicate that the salinity-ozone interaction is commercially important for leafy vegetable and forage crops. Because some crops are affected more by air pollutants when grown under nonsaline rather than saline conditions, such crops may seem more salt-tolerant in areas with high air pollution.

SALT TOLERANCE EVALUATIONS

Our current evaluation of the relative salt tolerance of agricultural crops is given in the Table. The alphabetical crop list provides two essential parameters sufficient for expressing salt tolerance: (1) the maximum allowable salinity without yield reduction below that of the nonsaline control treatment and (2) the percent yield decrease per unit salinity increase beyond the threshold. All the salinity values are reported as EC_e (in mmho/cm at 25C) and rounded to two significant digits. A qualitative salt tolerance rating is also given for quick, relative comparisons among crops. These ratings are defined by the boundaries shown in the Figure. The literature references upon which these evaluations are based are also listed in the Table.

The information for preparing this salt tolerance list was obtained by reviewing 1) salinity related references listed in the Bibliography of Agriculture from 1950 to 1975; 2) all available published and unpublished information at the U.S. Salinity Laboratory including the Laboratory's Collaborators' Reports; 3) the references listed in individual salt tolerance papers; and 4) results requested from research personnel in the western United States. In general, only those papers reporting measurements of both root-media salinity and crop yield were considered. Unfortunately, growth response had to be used for some tree and vine crops because of the lack of yield data. Experiments without adequate control of the factors influencing salt tolerance and papers that failed to mention these factors were not considered in the salt tolerance evaluations. Some crops listed in the Table have only a qualitative salt tolerance rating because of insufficient data for quantitative evaluation. For ease in interpretation, all salinity values were converted to the same measure, EC_e, and all yield data were placed on a relative basis with the yield of the control treatment assigned a value of 100.

After evaluating the data for the various crops it became apparent that, in general, yield was not decreased significantly until a threshold salinity level was exceeded, and that yield decreased approximately linearly as salinity increased beyond the threshold. With some crops, e.g., bean, onion, clover, and pepper, yield approached zero asymptotically; with a few others, yields decreased linearly as salinity increased to a point above which the plants died and yields dropped sharply to zero. These deviations from linearity are of little concern, however, because they occur only in the lower part of the curve where yields are commercially unacceptable. Nevertheless, salinity values may be extrapolated for zero yield to estimate the maximum salinities that plants can tolerate for calculating leaching requirements (41, 153).

To obtain the numerical evaluations presented in the Table, least-squares linear equations were fit to the data for each experiment for values beyond the threshold salinity. In some cases, inclusion or exclusion of data required subjective judgment. When more than one experiment was considered for determining the salt tolerance of a crop, the slope and intercept values for the various experiments were averaged. Because the salinity range studied in some experiments was poorly chosen, data from some experiments could only be used to establish threshold salinities and from others only to determine slope. From the average regression coefficients, the salinity levels at initial yield decline and the yield decrease per unit salinity increase were computed. Relative yield (Y) for any given soil salinity exceeding the threshold ($EC_e > A$) can be calculated by the equation

$$Y = 100 - B(EC_e - A) \qquad [1]$$

where A is the salinity threshold in mmho/cm and B the percent yield decrease per unit salinity increase. For example, alfalfa yields decrease approximately 7.3% per mmho/cm when the soil salinity exceeds 2.0 mmho/cm; therefore, at a soil salinity of 5.4 mmho/cm, the relative yield, $Y = 100 - 7.3(5.4 - 2.0) \simeq 75\%$.

Division boundaries for the salt tolerance ratings defined in the Figure were chosen to approximate the family of linear curves that represent the majority of the crops reported. Four divisions were labeled to correspond with previously published terminology ranging from sensitive to tolerant. With few exceptions the linear salt tolerance curves for each crop remained within one division. Where the linear salt tolerance curve for a crop crossed division boundaries, the crop was rated based on its tolerance at the lower salinity levels where yields are commercially acceptable.

A comparison of our salt tolerance evaluations with previously published data from this Laboratory (26, 28) revealed no major changes among the crops even though many evaluations included new and additional experimental data. Only the tolerance of garden beet and bermudagrass changed significantly and both seem less tolerant than previously reported. The threshold salinities of field corn, grape, and spinach dropped slightly as compared with extrapolated values from Bernstein's evaluations (28); whereas threshold salinities of cotton, soybean, and wheat increased about one mmho/cm. Several new crops were added to the list but quantative evaluations of a few others were not included because substantiating data were lacking.

The accuracy and reliability of these evaluations are no better than the data used to make them and can only be refined by further observation, experimentation and continued improvement of our experimental techniques. Hopefully, these comments will promote well-conducted and controlled experiments that will provide additional salt tolerance data to improve and expand this list.

SUMMARY

An extensive literature review of all available salt tolerance data was undertaken to evaluate the current status of our knowledge of the salt tolerance of agricultural crops. In general, crops tolerate salinity up to a threshold level above which yields decrease approximately linearly as salt concentrations increase. Our best estimate of the threshold salinity level and yield decrease per unit salinity increase is presented for a large number of agricultural crops. The methods of measuring appropriate salinity and plant parameters to obtain meaningful salt tolerance data and the many plant, soil, water and environmental factors influencing the plant's ability to tolerate salt are discussed.

Table. Salt tolerance of agricultural crops.

:rop	Salinity[a] at Initial Yield Decline (threshold) (A) mmho/cm	% Yield Decrease per Unit Increase in Salinity Beyond Threshold (B) %/(mmho/cm)	Salt Tolerance Rating[b]	References
:alfa *ledicago sativa*	2.0	7.3	MS	41, 46, 53, 56, 75, 9
nond[c] *?runus amygdalus*	1.5	19	S	35, 57
ole *?yrus malus*	---	---	S	99
:icot[c] *?yrus armeniaca*	1.6	24	S	35, 57
ocado[c] *?ersea americana*	---	---	S	13, 82
rley (forage)[d] *lordeum vulgare*	6.0	7.1	MT	63, 84
..y (grain)[d] *lordeum vulgare*	8.0	5.0	T	15, 84
an *?haseolus vulgaris*	1.0	19	S	31, 95, 118, 125, 128
et, garden[e] *Beta vulgaris*	4.0	9.0	MT	43, 96, 118
ıtgrass *Agrostis palustris*	---	---	MS	159
mudagrass[f] *Cynodon dactylon*	6.9	6.4	T	39, 40, 108
ackberry *Rubus* spp.	1.5	22	S	66
ysenberry *Rubus* spp.	1.5	22	S	66
oadbean *Vicia faba*	1.6	9.6	MS	1.

able. (continued)

Crop	Salinity[a] at Initial Yield Decline (threshold) (A)	% Yield Decrease per Unit Increase in Salinity beyond Threshold (B)	Salt Tolerance Rating[b]	References
	mmho/cm	%/(mmho/cm)		
Broccoli *Brassica oleracea italica*	2.8	9.2	MT	29, 43
Bromegrass *Bromus inermis*	---	---	MT	119
Cabbage *Brassica oleracea capitata*	1.8	9.7	MS	29, 43, 128
Canarygrass, reed *Phalaris arundinacea*	---	---	MT	119
Carrot *Daucus carota*	1.0	14	S	32, 43, 107, 118, 1
Clover, alsike, ladino, r ', strawberry *rifolium* spp.	1.5	12	MS	11, 39, 75, 144
Clover, berseem *T. alexandrinum*	1.5	5.7	MS	9, 16, 139, 14[illegible]
Corn (forage) *Zea mays*	1.8	7.4	MS	85, 138, 139
Corn (grain) *Zea mays*	1.7	12	MS	30, 102
Corn, sweet *Zea mays*	1.7	12	MS	30
Cotton *Gossypium hirsutum*	7.7	5.2	T	22, 23, 38
Cowpea *Vigna sinensis*	1.3	14	MS	13[illegible]

e. (continued)

:op	Salinity[a] at Initial Yield Decline (threshold) (A) mmho/cm	% Yield Decrease per Unit Increase in Salinity Beyond Threshold (B) %/(mmho/cm)	Salt Tolerance Rating[b]	References
umber ucumis sativus	2.5	13	MS	128, 137
e hoenix dactylifera	4.0	3.6	T	72, 73, 74
cue, tall estuca elatior	3.9	5.3	MT	54, 55
x inum usitatissimum	1.7	12	MS	89
ipe[c] 'itis spp.	1.5	9.6	MS	81, 124, 150
ipefruit[c] :itrus paradisi	1.8	16	S	86, 91, 135
nggrass halaris tuberosa	4.6	7.6	MT	55
non[c] Citrus limonia	---	---	S	64
ttuce Lactuca sativa	1.3	13	MS	19, 43, 128
vegrass[g] Eragrostis spp.	2.0	8.4	MS	39
adow Foxtail Alopecurus pratensis	1.5	9.6	MS	55
llet, Foxtail Setaria italica	---	---	MS	139
:ra Hibiscus esculentus	---	---	S	6, 122, 130
.ive Olea europaea	---	---	MT	48, 150

Table. (continued)

Crop	Salinity[a] at Initial Yield Decline (theshold) (A)	% Yield Decrease per Unit Increase in Salinity Beyond Threshold (B)	Salt Tolerance Rating[b]	References
	mmho/cm	%/(mmho/cm)		
Sesbania[d] *Sesbania macrocarpa*	2.3	7.0	MS	23
Sorghum *Sorghum bicolor*	---	---	MS	64
Soybean *Glycine max*	5.0	20	MT	2, 45,46
Spinach *Spinacia oleracea*	2.0	7.6	MS	109, 128
Strawberry *Fragaria* spp.	1.0	33	S	67, 128
Sudangrass *Sorghum sudanense*	2.8	4.3	MT	54
Sugarbeet[e] *eta vulgaris*	7.0	5.9	T	52, 155
ugarcane *Saccharum officinarum*	1.7	5.9	MS	42, 62, 149
weet potato *Ipomoea batatas*	1.5	11	MS	80, U
imothy *Phleum pratense*	---	---	MS	144
omato *Lycopersicon esculentum*	2.5	9.9	MS	49, 87, 166, 148
refoil, Big *Lotus uliginosus*	2.3	19	MS	11, 12
refoil, Birdsfoot arrowleaf[i] *L. corniculatus tenuifolius*	5.0	10	MT	11, 12
etch, common *Vicia sativa*	3.0	11	MS	139

Table. (continued)

Crop	Salinity[a] at Initial Yield Decline (threshold) (A) mmho/cm	% Yield Decrease per Unit Increase in Salinity Beyond Threshold (B) %/(mmho/cm)	Salt Tolerance Rating[b]	References
Wheat[d,j] *Triticum aestivum*	6.0	7.1	MT	8, 15, 90
Wheatgrass, crested *Agropyron desertorum*	3.5	4.0	MT	37
Wheatgrass, fairway *A. cristatum*	7.5	6.9	T	37
Wheatgrass, slender *A. trachycaulum*	---	---	MT	119
Wheatgrass, tall *A. elongatum*	7.5	4.2	T	37
Wildrye, Altai *Elymus angustus* Trin.	---	---	T	119
Wildrye, Beardless *. triticoides*	2.7	6.0	MT	55
Wildrye, Russian *E. junceus*	---	---	T	119

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[a] Salinity expressed as EC_e (in mmho/cm at 25C).

[b] Ratings are defined by the boundaries in the Figure.

[c] Tolerance is based on growth rather than yield.

[d] Less tolerant during emergence and seedling stage. EC_e should not exceed 4 or 5 mmho/cm.

[e] Sensitive during germination. EC_e should not exceed 3 mmho/cm for beet and sugarbeet.

[f] Average of several varieties. Suwannee and Coastal are about 20% more tolerant, and Common and Greenfield are about 20% less tolerant than the average.

[g] Average for Boer, Wilman, Sand and Weeping varieties. Lehmann seems about 50% more tolerant.

[h] Unpublished US Salinity Laboratory data.

[i] Broadleaf birdsfoot trefoil seems less tolerant than narrowleaf.

[j] Tolerance data may not apply to new semidwarf varieties.

APPENDIX 1-REFERENCES

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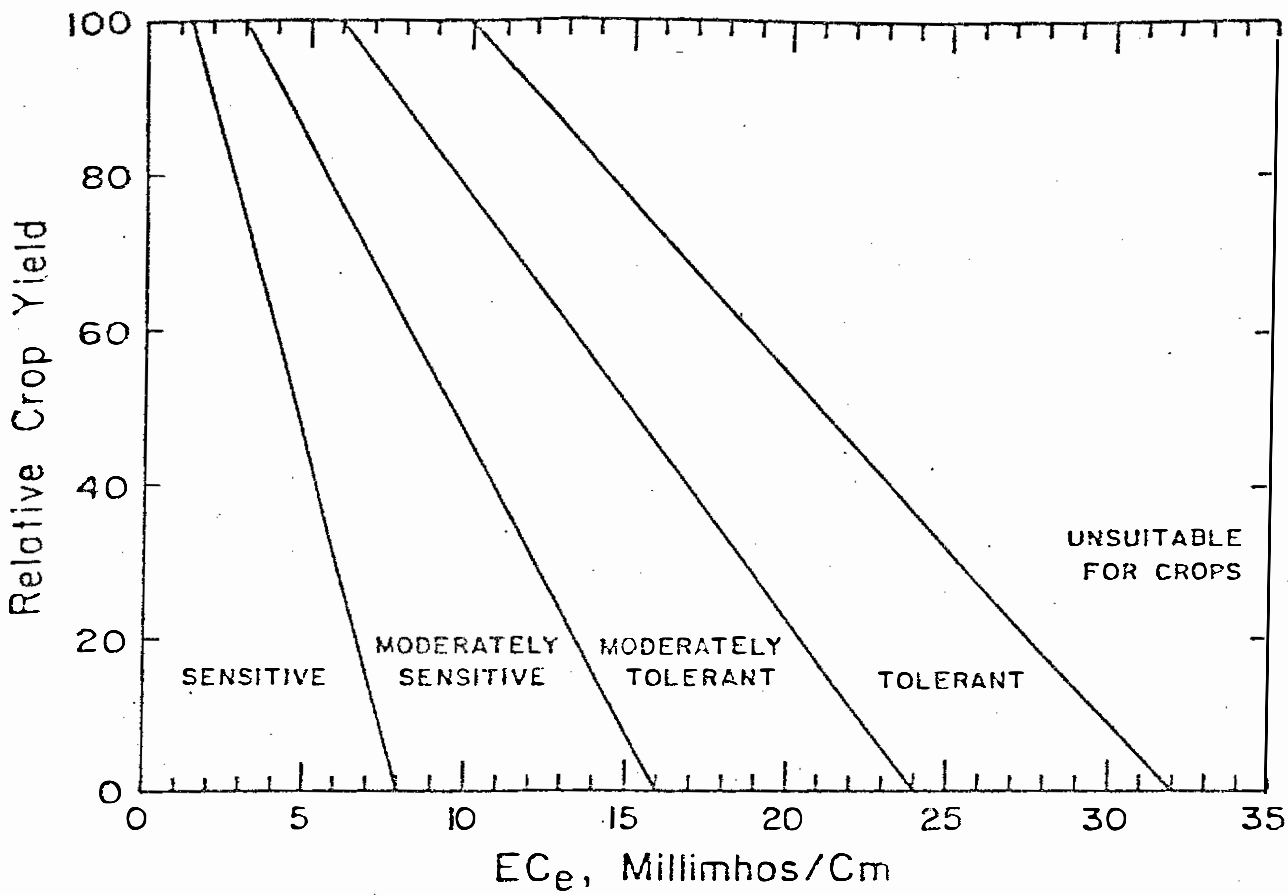

Divisions for classifying crop tolerance to salinity