# TECHNICAL NOTES

U S Department of Agriculture Natural Resources Conservation Service

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## CROP TOLERANCE AND YIELD POTENTIAL OF SELECTED CROPS AS INFLUENCED BY IRRIGATION WATER SALINITY ($EC_w$) OR SOIL SALINITY ($EC_e$) [1]

### Introduction

A salinity problem exists if the accumulation of salt in the root zone is at a concentration that causes a reduction in yield. Salts originate from saline soils, soils with a high saline water table or from salts in the irrigation water. Yield reductions occur when the crop is no longer able to extract sufficient water from the salty soil-water solution.

Plant salinity tolerance varies between crops. Crops such as cotton and barley can produce acceptable yields at much greater soil salinity levels than crops such as corn and soybeans. This is because certain crops can make osmotic adjustments that enable them to extract more water from a saline soil. The ability of the crop to adjust to salinity is extremely useful. When soil salinity cannot be controlled at an acceptable concentration for the planned crop, an alternative more salt tolerant crop can be selected and that can produce economical yields.

The purpose of this technical note is to provide planners soil salinity ($EC_e$) and water salinity ($EC_w$) values of various crops to assist them in determining potential yield reductions based on soil and water tests. The $EC_e$ and $EC_w$ values in the table below are in deciSiemens per meter (dS/m). The table below is to be used to determine based on $EC_e$ if "Soil Contaminants—excess salts" is a Resource Concern.

Example: growing cotton and the soil salinity ($EC_e$) is 7.8 dS/m; you would expect no or Zero (0%) potential yield reduction. However, if the cotton field had an $EC_e$ of 10 dS/m then you would expect a potential yield reduction of 10%.

This technical note was adapted from "Water Quality for Agriculture" by Ayers and Westcot, 1985, Table 4 CROP TOLERANCE AND YIELD POTENTIAL OF SELECTED CROPS AS INFLUENCED BY IRRIGATION WATER SALINITY ($EC_w$) OR SOIL SALINITY ($EC_e$), published by the United Nations-FAO.

For additional information this publication can be accessed at http://www.fao.org/docrep/003/t0234e/T0234E03.htm.

## YIELD REDUCTION POTENTIAL[2]

| Field Crops | 0% | | 10% | | 25% | | 50% | | 100% "maximum"[3] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ |
| **Barley** *(Hordeum vulgare)*[4] | 8.0 | 5.3 | 10 | 6.7 | 13 | 8.7 | 18 | 12 | 28 | 19 |
| **Cotton** *(Gossypium hirsutum)* | 7.7 | 5.1 | 9.6 | 6.4 | 13 | 8.4 | 17 | 12 | 27 | 18 |
| **Sugarbeet** *(Beta vulgaris)*[5] | 7.0 | 4.7 | 8.7 | 5.8 | 11 | 7.5 | 15 | 10 | 24 | 16 |
| **Sorghum** *(Sorghum bicolor)* | 6.8 | 4.5 | 7.4 | 5.0 | 8.4 | 5.6 | 9.9 | 6.7 | 13 | 8.7 |
| **Wheat** *(Triticum aestivum)*[4,6] | 6.0 | 4.0 | 7.4 | 4.9 | 9.5 | 6.3 | 13 | 8.7 | 20 | 13 |
| **Wheat, durum** *(Triticum turgidum)* | 5.7 | 3.8 | 7.6 | 5.0 | 10 | 6.9 | 15 | 10 | 24 | 16 |
| **Soybean** *(Glycine max)* | 5.0 | 3.3 | 5.5 | 3.7 | 6.3 | 4.2 | 7.5 | 5.0 | 10 | 6.7 |
| **Cowpea** *(Vigna unguiculata)* | 4.9 | 3.3 | 5.7 | 3.8 | 7.0 | 4.7 | 9.1 | 6.0 | 13 | 8.8 |
| **Peanut** *(Arachis hypogaea)* | 3.2 | 2.1 | 3.5 | 2.4 | 4.1 | 2.7 | 4.9 | 3.3 | 6.6 | 4.4 |
| **Rice (paddy)** *(Oriza sativa)* | 3.0 | 2.0 | 3.8 | 2.6 | 5.1 | 3.4 | 7.2 | 4.8 | 11 | 7.6 |
| **Sugarcane** *(Saccharum officinarum)* | 1.7 | 1.1 | 3.4 | 2.3 | 5.9 | 4.0 | 10 | 6.8 | 19 | 12 |
| **Corn (maize)** *(Zea mays)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Flax** *(Linum usitatissimum)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Broadbean** *(Vicia faba)* | 1.5 | 1.1 | 2.6 | 1.8 | 4.2 | 2.0 | 6.8 | 4.5 | 12 | 8.0 |
| **Bean** *(Phaseolus vulgaris)* | 1.0 | 0.7 | 1.5 | 1.0 | 2.3 | 1.5 | 3.6 | 2.4 | 6.3 | 4.2 |
| **Vegetable Crops** | | | | | | | | | | |
| **Squash, zucchini (courgette)** *(Cucurbita pepo melopepo)* | 4.7 | 3.1 | 5.8 | 3.8 | 7.4 | 4.9 | 10 | 6.7 | 15 | 10 |
| **Beet, red** *(Beta vulgaris)*[5] | 4.0 | 2.7 | 5.1 | 3.4 | 6.8 | 4.5 | 9.6 | 6.4 | 15 | 10 |
| **Squash, scallop** *(Cucurbita pepo melopepo)* | 3.2 | 2.1 | 3.8 | 2.6 | 4.8 | 3.2 | 6.3 | 4.2 | 9.4 | 6.3 |
| **Broccoli** *(Brassica oleracea botrytis)* | 2.8 | 1.9 | 3.9 | 2.6 | 5.5 | 3.7 | 8.2 | 5.5 | 14 | 9.1 |
| **Tomato** *(Lycopersicon esculentum)* | 2.5 | 1.7 | 3.5 | 2.3 | 5.0 | 3.4 | 7.6 | 5.0 | 13 | 8.4 |
| **Cucumber** *(Cucumis sativus)* | 2.5 | 1.7 | 3.3 | 2.2 | 4.4 | 2.9 | 6.3 | 4.2 | 10 | 6.8 |
| **Spinach** *(Spinacia oleracea)* | 2.0 | 1.3 | 3.3 | 2.2 | 5.3 | 3.5 | 8.6 | 5.7 | 15 | 10 |
| **Celery** *(Apium graveolens)* | 1.8 | 1.2 | 3.4 | 2.3 | 5.8 | 3.9 | 9.9 | 6.6 | 18 | 12 |
| **Cabbage** *(Brassica oleracea capitata)* | 1.8 | 1.2 | 2.8 | 1.9 | 4.4 | 2.9 | 7.0 | 4.6 | 12 | 8.1 |
| **Potato** *(Solanum tuberosum)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Corn, sweet (maize)** *(Zea mays)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Sweet potato** *(Ipomoea batatas)* | 1.5 | 1.0 | 2.4 | 1.6 | 3.8 | 2.5 | 6.0 | 4.0 | 11 | 7.1 |
| **Pepper** *(Capsicum annuum)* | 1.5 | 1.0 | 2.2 | 1.5 | 3.3 | 2.2 | 5.1 | 3.4 | 8.6 | 5.8 |
| **Lettuce** *(Lactuca sativa)* | 1.3 | 0.9 | 2.1 | 1.4 | 3.2 | 2.1 | 5.1 | 3.4 | 9.0 | 6.0 |
| **Radish** *(Raphanus sativus)* | 1.2 | 0.8 | 2.0 | 1.3 | 3.1 | 2.1 | 5.0 | 3.4 | 8.9 | 5.9 |
| **Onion** *(Allium cepa)* | 1.2 | 0.8 | 1.8 | 1.2 | 2.8 | 1.8 | 4.3 | 2.9 | 7.4 | 5.0 |
| **Carrot** *(Daucus carota)* | 1.0 | 0.7 | 1.7 | 1.1 | 2.8 | 1.9 | 4.6 | 3.0 | 8.1 | 5.4 |
| **Bean** *(Phaseolus vulgaris)* | 1.0 | 0.7 | 1.5 | 1.0 | 2.3 | 1.5 | 3.6 | 2.4 | 6.3 | 4.2 |
| **Turnip** *(Brassica rapa)* | 0.9 | 0.6 | 2.0 | 1.3 | 3.7 | 2.5 | 6.5 | 4.3 | 12 | 8.0 |
| **Forage/Cover Crops** | | | | | | | | | | |
| **Wheatgrass, tall** *(Agropyron elongatum)* | 7.5 | 5.0 | 9.9 | 6.6 | 13 | 9.0 | 19 | 13 | 31 | 21 |
| **Wheatgrass, fairway crested** *(Agropyron cristatum)* | 7.5 | 5.0 | 9.0 | 6.0 | 11 | 7.4 | 15 | 9.8 | 22 | 15 |
| **Bermuda grass** *(Cynodon dactylon)*[7] | 6.9 | 4.6 | 8.5 | 5.6 | 11 | 7.2 | 15 | 9.8 | 23 | 15 |
| **Ryegrass, perennial** *(Lolium perenne)* | 5.6 | 3.7 | 6.9 | 4.6 | 8.9 | 5.9 | 12 | 8.1 | 19 | 13 |
| **Trefoil, narrowleaf birdsfoot**[8] *(Lotus corniculatus tenuifolium)* | 5.0 | 3.3 | 6.0 | 4.0 | 7.5 | 5.0 | 10 | 6.7 | 15 | 10 |
| **Harding grass** *(Phalaris tuberosa)* | 4.6 | 3.1 | 5.9 | 3.9 | 7.9 | 5.3 | 11 | 7.4 | 18 | 12 |
| **Fescue, tall** *(Festuca elatior)* | 3.9 | 2.6 | 5.5 | 3.6 | 7.8 | 5.2 | 12 | 7.8 | 20 | 13 |
| **Wheatgrass, standard crested** *(Agropyron sibiricum)* | 3.5 | 2.3 | 6.0 | 4.0 | 9.8 | 6.5 | 16 | 11 | 28 | 19 |

| **Forage/Cover Crops-cont'd** | **0%** | | **10%** | | **25%** | | **50%** | | **100% "maximum"[3]** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **$EC_e$** | **$EC_w$** | **$EC_e$** | **$EC_w$** | **$EC_e$** | **$EC_w$** | **$EC_e$** | **$EC_w$** | **$EC_e$** | **$EC_w$** |
| **Vetch, common** *(Vicia angustifolia)* | 3.0 | 2.0 | 3.9 | 2.6 | 5.3 | 3.5 | 7.6 | 5.0 | 12 | 8.1 |
| **Sudan grass** *(Sorghum sudanense)* | 2.8 | 1.9 | 5.1 | 3.4 | 8.6 | 5.7 | 14 | 9.6 | 26 | 17 |
| **Wildrye, beardless** *(Elymus triticoides)* | 2.7 | 1.8 | 4.4 | 2.9 | 6.9 | 4.6 | 11 | 7.4 | 19 | 13 |
| **Cowpea (forage)** *(Vigna unguiculata)* | 2.5 | 1.7 | 3.4 | 2.3 | 4.8 | 3.2 | 7.1 | 4.8 | 12 | 7.8 |
| **Trefoil, big** *(Lotus uliginosus)* | 2.3 | 1.5 | 2.8 | 1.9 | 3.6 | 2.4 | 4.9 | 3.3 | 7.6 | 5.0 |
| **Sesbania** *(Sesbania exaltata)* | 2.3 | 1.5 | 3.7 | 2.5 | 5.9 | 3.9 | 9.4 | 6.3 | 17 | 11 |
| **Sphaerophysa** *(Sphaerophysa salsula)* | 2.2 | 1.5 | 3.6 | 2.4 | 5.8 | 3.8 | 9.3 | 6.2 | 16 | 11 |
| **Alfalfa** *(Medicago sativa)* | 2.0 | 1.3 | 3.4 | 2.2 | 5.4 | 3.6 | 8.8 | 5.9 | 16 | 10 |
| **Lovegrass** *(Eragrostis sp.)*[9] | 2.0 | 1.3 | 3.2 | 2.1 | 5.0 | 3.3 | 8.0 | 5.3 | 14 | 9.3 |
| **Corn (forage) (maize)** *(Zea mays)* | 1.8 | 1.2 | 3.2 | 2.1 | 5.2 | 3.5 | 8.6 | 5.7 | 15 | 10 |
| **Clover, berseem** *(Trifolium alexandrinum)* | 1.5 | 1.0 | 3.2 | 2.2 | 5.9 | 3.9 | 10 | 6.8 | 19 | 13 |
| **Orchard grass** *(Dactylis glomerata)* | 1.5 | 1.0 | 3.1 | 2.1 | 5.5 | 3.7 | 9.6 | 6.4 | 18 | 12 |
| **Foxtail, meadow** *(Alopecurus pratensis)* | 1.5 | 1.0 | 2.5 | 1.7 | 4.1 | 2.7 | 6.7 | 4.5 | 12 | 7.9 |
| **Clover, red** *(Trifolium pratense)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Clover, alsike** *(Trifolium hybridum)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Clover, ladino** *(Trifolium repens)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Clover, strawberry** *(Trifolium fragiferum)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Fruit Crops**[10] | | | | | | | | | | |
| **Date palm** *(phoenix dactylifera)* | 4.0 | 2.7 | 6.8 | 4.5 | 11 | 7.3 | 18 | 12 | 32 | 21 |
| **Grapefruit** *(Citrus paradisi)*[11] | 1.8 | 1.2 | 2.4 | 1.6 | 3.4 | 2.2 | 4.9 | 3.3 | 8.0 | 5.4 |
| **Orange** *(Citrus sinensis)* | 1.7 | 1.1 | 2.3 | 1.6 | 3.3 | 2.2 | 4.8 | 3.2 | 8.0 | 5.3 |
| **Peach** *(Prunus persica)* | 1.7 | 1.1 | 2.2 | 1.5 | 2.9 | 1.9 | 4.1 | 2.7 | 6.5 | 4.3 |
| **Apricot** *(Prunus armeniaca)*[11] | 1.6 | 1.1 | 2.0 | 1.3 | 2.6 | 1.8 | 3.7 | 2.5 | 5.8 | 3.8 |
| **Grape** *(Vitus sp.)*[11] | 1.5 | 1.0 | 2.5 | 1.7 | 4.1 | 2.7 | 6.7 | 4.5 | 12 | 7.9 |
| **Almond** *(Prunus dulcis)*[11] | 1.5 | 1.0 | 2.0 | 1.4 | 2.8 | 1.9 | 4.1 | 2.8 | 6.8 | 4.5 |
| **Plum, prune** *(Prunus domestica)*[11] | 1.5 | 1.0 | 2.1 | 1.4 | 2.9 | 1.9 | 4.3 | 2.9 | 7.1 | 4.7 |
| **Blackberry** *(Rubus sp.)* | 1.5 | 1.0 | 2.0 | 1.3 | 2.6 | 1.8 | 3.8 | 2.5 | 6.0 | 4.0 |
| **Boysenberry** *(Rubus ursinus)* | 1.5 | 1.0 | 2.0 | 1.3 | 2.6 | 1.8 | 3.8 | 2.5 | 6.0 | 4.0 |
| **Strawberry** *(Fragaria sp.)* | 1.0 | 0.7 | 1.3 | 0.9 | 1.8 | 1.2 | 2.5 | 1.7 | 4 | 2.7 |

[1] Adapted from Ayers and Westcot, 1985, Water Quality for Agriculture, FAO, United Nations. These data should only serve as a guide to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions and cultural practices. In gypsiferous soils, plants will tolerate about 2 dS/m higher soil salinity (ECe) than indicated but the water salinity (ECw) will remain the same as shown in this table.

[2] ECe means average root zone salinity as measured by electrical conductivity of the saturation extract of the soil, reported in deciSiemens per meter (dS/m) at 25°C. ECw means electrical conductivity of the irrigation water in deciSiemens per meter (dS/m). The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15–20 percent leaching fraction and a 40-30-20-10 percent water use pattern for the upper to lower quarters of the root zone. These assumptions were used in developing the guidelines in Table 1.

[3] The zero yield potential or maximum ECe indicates the theoretical soil salinity (ECe) at which crop growth ceases.

[4] Barley and wheat are less tolerant during germination and seeding stage; ECe should not exceed 4–5 dS/m in the upper soil during this period.

[5] Beets are more sensitive during germination; ECe should not exceed 3 dS/m in the seeding area for garden beets and sugar beets.

[6] Semi-dwarf, short cultivars may be less tolerant.

[7] Tolerance given is an average of several varieties; Suwannee and Coastal Bermuda grass are about 20 percent more tolerant, while Common and Greenfield Bermuda grass are about 20percent less tolerant.

[8] Broadleaf Birdsfoot Trefoil seems less tolerant than Narrowleaf Birdsfoot Trefoil.

[9] Tolerance given is an average for Boer, Wilman, Sand and Weeping Lovegrass; Lehman Lovegrass seems about 50 percent more tolerant.

[10] These data are applicable when rootstocks are used that do not accumulate $Na^+$ and $Cl^-$ rapidly or when these ions do not predominate in the soil. If either ions do accumulate or predominate in the soil, refer to the toxicity discussion in Section 4 of Ayers and Westcot, 1985, Water Quality for Agriculture publication.

[11] Tolerance is based on tree growth and not on yield.

## Other References

University of Arizona Extension Publication "Salinity Handbook for Arizona Extension Workers", 1961.

USDA-NRCS Arizona Agronomy Tech Note 54, "Conversion Chart of Equivalent Units of Soil Amendments", May 1974.

USDA-NRCS Arizona Agronomy Tech Note 57, "Leaching Needs in Irrigation Water Management", January 1975.

UDSA-ARS Handbook 60, Saline and Alkaline Soils
http://www.ars.usda.gov/Services/docs.htm?docid=10158

University of Arizona Cooperative Extension publication, "Leaching for Maintenance – Factors to Consider for Determining the Leaching Requirements of Crops"
http://ag.arizona.edu/pubs/water/az1107.pdf