Crop tolerance

Eugene V. Maas

One strategy available to farmers with saline soils is to select salt-tolerant crops. Crop tolerance to salinity ranges widely from the very salt-sensitive bean to the highly tolerant barley and cotton.

The U.S. Salinity Laboratory in Riverside has been testing the salt tolerance of crops since it was established in 1937. It now has data on nearly 70 crops, which will be useful in predicting responses on saline soils (see table). Experiments recently completed or in progress will provide additional data on asparagus, bread wheat, durum wheat, triticale, sorghum, sugarbeet, and guayule. Five or six crops can be tested per year to year, but the relative yield reductions caused by salinity remain reasonably consistent.

Crop tolerance tests are usually conducted in small experimental plots, where commercial practices are followed as closely as possible, with adequate moisture and fertility. To ensure an acceptable stand, researchers plant seed in a nonsaline seedbed and impose salinity by adding calcium and sodium chloride salts to the irrigation water after the seedlings have emerged. They test several salinity levels to determine both the threshold level that begins to decrease yield and the rate of yield reduction caused by higher levels. Generally, the higher the threshold level, the less yield is decreased as salinity increases.

Because numerous plant, soil, and weather conditions also affect crop growth, yield must be expressed as a percentage of that obtained under similar but nonsaline conditions. Actual yields vary from location to location and year to year, but the relative yield reductions caused by salinity remain reasonably consistent.

Soil salinity in the plant root zone is conveniently measured as electrical conductivity, which is directly proportional to the salt concentration in the soil water. Two commonly used methods pro-

Small plots of wheat are used to determine salt tolerance. Salts are added to irrigation water after seedlings have emerged to determine the point at which salt damage begins to appear and the rate of yield reduction.

Although our knowledge of the mechanisms of salt tolerance and sensitivity in plants is still scant, we are beginning to understand some of the fundamental differences between halophytes and glycophytes. Crops (mostly glycophytic) are comparatively salt-sensitive, salinity causing osmotic and ion-specific effects leading to reduction in growth and yield. Much research in the past has put emphasis on the osmotic effects of salinity, whereby the availability of water to the plant is diminished. Our research, however, leads to the conclusion that specific ion effects deserve at least "equal billing" as the cause of salt-induced reduction in the growth of crops.

We need to identify physiological markers related to salt resistance that may be used in genetic improvement of crops for high productivity in salt-affect ed soils. Physiological studies with genetic lines differing in salt resistance and investigations comparing cultivated species and wild, salt-tolerant relatives will help in achieving this goal.

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The more salt tolerant a crop is, the less yield decreases as salinity rises.

Saturating the soil with salt introduces several problems. It is difficult to predict yield losses as related to salinity levels in sprinkler irrigation water. Greenhouse experiments conducted at the U.S. Salinity Lab to test the susceptibility of various crops to foliar injury from saline sprinkling waters indicate that tolerance is related more to the amount of salt absorbed by the leaves than to their tolerance to soil salinity. The degree of injury depends on weather conditions and water stress. For instance, leaves may contain excessive levels of salt for several weeks without any visible injury symptoms and then become severely burned when the weather becomes hot and dry.

It is reasonable to assume that saline irrigation water will reduce yields of sprinkled crops at least as much as those of surface-irrigated crops. Additional reductions in yield could be expected for crops susceptible to sprinkler-induced foliar injury.

Unlike most annual crops, tree fruit crops are sensitive to specific salt constituents and often develop leaf burn symptoms from toxic levels of sodium or chloride. Different varieties and rootstocks accumulate these ions at different rates, and so each one must be evaluated individually. Because it is difficult to obtain such data on producing trees, the figures are usually based on vegetative growth of young trees rather than on yield; consequently, they provide only general guidelines.

Salt tolerance ratings cannot provide accurate estimates of actual crop yields, which depend on many other growing conditions, including weather, fertility, soil type, water stress, insects, and disease. The ratings are useful, however, in predicting how one crop might fare relative to another on saline soils under different cultural conditions. As such, they are valuable aids in managing salinity problems in irrigated agriculture.

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**Salt tolerance of agricultural crops**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maximum soil salinity without yield loss (threshold)</th>
<th>% Decrease in yield at soil salinities above the threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitive crops</strong></td>
<td>dS/m (%)</td>
<td></td>
</tr>
<tr>
<td>Bean</td>
<td>1.0 (19)</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>1.0 (14)</td>
<td></td>
</tr>
<tr>
<td>Strawberry</td>
<td>1.0 (33)</td>
<td></td>
</tr>
<tr>
<td>Onions</td>
<td>1.2 (16)</td>
<td></td>
</tr>
<tr>
<td>Almonds</td>
<td>1.5 (19)</td>
<td></td>
</tr>
<tr>
<td>Blackberry</td>
<td>1.5 (22)</td>
<td></td>
</tr>
<tr>
<td>Boysenberry</td>
<td>1.5 (22)</td>
<td></td>
</tr>
<tr>
<td>Plum, prune†</td>
<td>1.5 (18)</td>
<td></td>
</tr>
<tr>
<td>Apricots</td>
<td>1.6 (24)</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>1.7 (16)</td>
<td></td>
</tr>
<tr>
<td>Peach</td>
<td>1.7 (21)</td>
<td></td>
</tr>
<tr>
<td>Grapefruit†</td>
<td>1.8 (16)</td>
<td></td>
</tr>
<tr>
<td><strong>Moderately sensitive crops</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnip</td>
<td>0.9 (9.0)</td>
<td></td>
</tr>
<tr>
<td>Radish</td>
<td>1.2 (13)</td>
<td></td>
</tr>
<tr>
<td>Lettuce</td>
<td>1.3 (13)</td>
<td></td>
</tr>
<tr>
<td>Clover, berseem</td>
<td>1.5 (5.7)</td>
<td></td>
</tr>
<tr>
<td>Clover, strawberry</td>
<td>1.5 (12)</td>
<td></td>
</tr>
<tr>
<td>Clover, red</td>
<td>1.5 (12)</td>
<td></td>
</tr>
<tr>
<td>Clover, alisike</td>
<td>1.5 (12)</td>
<td></td>
</tr>
<tr>
<td>Clover, laudanum</td>
<td>1.5 (12)</td>
<td></td>
</tr>
<tr>
<td>Foxtail, meadow</td>
<td>1.5 (9.6)</td>
<td></td>
</tr>
<tr>
<td>Grape†</td>
<td>1.5 (9.6)</td>
<td></td>
</tr>
<tr>
<td>Orachegrass</td>
<td>1.5 (6.2)</td>
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</tr>
<tr>
<td>Pepper</td>
<td>1.5 (14)</td>
<td></td>
</tr>
<tr>
<td>Sweet potato</td>
<td>1.5 (11)</td>
<td></td>
</tr>
<tr>
<td>Broadbean</td>
<td>1.6 (9.6)</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>1.7 (12)</td>
<td></td>
</tr>
<tr>
<td>Flax</td>
<td>1.7 (12)</td>
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</tr>
<tr>
<td>Potato</td>
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<tr>
<td>Sugarcane</td>
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<td>Cabbage</td>
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<tr>
<td>Celery</td>
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<tr>
<td>Corn (forage)</td>
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<tr>
<td>Alfalfa</td>
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</tr>
<tr>
<td>Spinach</td>
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</tr>
<tr>
<td>Trefoil, big</td>
<td>2.3 (19)</td>
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</tr>
<tr>
<td>Cowpea (forage)</td>
<td>2.5 (11)</td>
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</tr>
<tr>
<td>Cucumber</td>
<td>2.5 (13)</td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>2.5 (9.9)</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>2.8 (9.2)</td>
<td></td>
</tr>
<tr>
<td>Vetch, common</td>
<td>3.0 (11)</td>
<td></td>
</tr>
<tr>
<td>Rice, paddy†</td>
<td>3.0§ (12§)</td>
<td></td>
</tr>
<tr>
<td>Squash, scallop</td>
<td>3.2 (16)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Maas, E. V. 1984. Salt tolerance of plants. In Handbook of Plant Science in Agriculture (ed.) B. R. Christie. CRC Press Inc., Boca Raton, Florida. (in press)  "Soil salinity expressed as electrical conductivity of saturated soil extracts. 1 decisiemens per meter (dS/m) = 1 millimho per centimeter (mmho/cm). 1 dS/m = approximately 643 mg/L salt. †Tolerance is based on growth rather than yield. ‡Less tolerant during emergence and seedling stage. §Values for paddy rice refer to the electrical conductivity of the soil water during the flooded growing conditions."