Water quality for irrigation

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By P. R. George, Research Officer, Salinity and Hydrology Research Branch

Although irrigation and salinity problems are frequently inseparable, there is a range of management methods that can be used to handle marginal quality water. Frequently these methods are simple, but require careful planning.

The wide range in the tolerance of crops to salinity can be exploited to ensure that appropriate crops are selected for the water available.

Because crops vary in their sensitivity to salt uptake in the leaves or the roots, watering methods can be changed to avoid problems. For profitable production enough water should be applied to ensure adequate water is available for plant growth as well as to leach excess salts out of the root zone.

Even with good quality water salt problems will occur in areas with watertables close to the surface, so effective drainage is essential for healthy growth.

Appropriate crop selection, cultural methods and water management allow saline water to be used to produce profitable crops.

Water quality criteria

Salts are always present in natural waters and can consist of a range of soluble chemicals including common salt (sodium chloride). In Western Australian waters salts are often present in high concentrations which can cause irrigation problems.

Unless the quantity and composition of these salts are known, the farmer cannot make appropriate decisions about the crops to grow and methods of water management. All irrigation water should be tested to determine its salt content.
Irrigation water quality is normally based on three criteria related to the concentration and composition of soluble salts. These are:

**Salinity** — the effect that dissolved salt has on plant growth in inducing what is called osmotic stress. Osmotic stress is similar to drought stress because salts reduce the availability of soil water to plant roots.

**Toxicity** — the effect that certain components of the water have on plant growth, reducing yields or causing tissue damage or nutrient imbalance. Toxicity can result from both leaf and root uptake of toxic elements.

**Sodicity** — some waters contain too much sodium relative to calcium and magnesium. Because of the adsorption of this sodium onto clay particles, soil structure is destroyed, leading to infiltration, waterlogging, soil crusting and cultivation problems.

The suitability of irrigation water cannot be properly assessed without knowing the crop to be grown, soil type and irrigation method to be used. An understanding of the reactions of plants and soils to increasing salt levels in the water is important.

### Composition of irrigation water

The concentration of salt in irrigation water can be measured by evaporating a sample of water to dryness, weighing the residue and expressing the salt content as milligrams per litre (mg/L). The total salt concentration in irrigation water can also be measured by using the rapid and direct electrical conductivity method. As the salt content of water increases so does its ability to conduct electricity. Thus the higher the electrical conductivity (EC), the higher the salt content. Because of its directness and convenience, electrical conductivity is now used as the standard measure of salt content.

Electrical conductivity is measured in milliSiemens per metre (mS/m). It can be used to estimate the concentration of salts in mg/L by the use of a conversion factor. Unfortunately, the conversion factor can vary with salinity levels so for this reason it is more desirable to use the electrical conductivity directly to assess the salinity of water.

The salt content of water is made up mainly of the cations (positively charged particles) such as calcium, magnesium, sodium and potassium and the anions (negatively charged particles) such as chloride, bicarbonate and sulphate. Waters, especially bore waters, occasionally contain significant amounts of other constituents such as carbonate, iron, nitrate and trace elements such as boron and fluoride. Although even low concentrations of boron and fluoride can be toxic to plants, most toxicity problems in Western Australia are caused by high concentrations of sodium and chloride.

Sodium, calcium and magnesium concentrations are also used to measure the water’s ability to cause sodicity, or soil structural problems. These problems are not common in the South-West Land Division, but in some northern areas where waters containing high bicarbonate levels are used on clayey soils, sodicity can be a problem.

The compositions and concentrations of irrigation waters vary widely. Surface waters are usually fresher than underground waters, unless the former are affected by seepage into the storage.

Bore water quality can change with the duration of pumping, though this is generally restricted to areas where salt water can intrude from estuaries or the sea. It is much more common to find significant differences between bore waters at different locations, even when relatively closely spaced. This is caused by changes in the underground water-bearing strata.

### Salinity assessment

Once the water salinity is known, crop salt tolerance and the leaching fraction, which is the proportion of applied water that is available to leach salts from the root zone, should be assessed.

**Crop tolerance**

Agricultural crops vary widely in their tolerance of salinity. Depending on the crop, there is a range of permissible salinity levels of irrigation water.

The United States Salinity Laboratories have provided the most complete classification of plant salt tolerance. This is based on a threshold salinity level, that is the soil salinity level at which yield falls below its potential maximum, and the rate at which yield declines with increasing salinity beyond the threshold level. The classification uses soil salinity expressed as the electrical conductivity of the soil solution drawn off from a saturated soil (ECₑ). The ECₑ accounts for differences in the water holding capacity of the soil which will result in different dilutions of the mass of salt contained in the soil. The higher the ECₑ, the higher the soil salinity.

Table 1 lists some of the plants in each salt tolerance category, together with precautions required during irrigation.

As crop yields decline steadily with increasing soil salinity, yield losses may go undetected because obvious leaf symptoms do not appear. The gradual yield decline means that a grower using good water management and cultural practices can still produce a profitable, though not maximum-yielding, crop with saline water. Where a range of different quality waters is available for irrigation and a range of crops is grown, plant growth problems may be avoided by matching water quality with crop tolerance.
Table 1. Salt tolerance rankings of some agricultural crops together with desirable irrigation precautions.

<table>
<thead>
<tr>
<th>Ranking*</th>
<th>Crops</th>
<th>Irrigation precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitive</td>
<td>Apple, Avocado, Stone fruits, Strawberry, Citrus, Beans, Carrot</td>
<td>Avoid wetting leaves on hot days.</td>
</tr>
<tr>
<td>Moderately sensitive</td>
<td>Clover, Grape, Lettuce, Potato, Tomato, Maize, Lucerne</td>
<td>Avoid wetting leaves during daytime. Ensure leaching requirement is met. Use continuous wetting large droplet sprinklers if wetting leaves. Use of micro-irrigation methods may be warranted.</td>
</tr>
<tr>
<td>Moderately tolerant</td>
<td>Sorghum, Soybean, Wheat, Safflower, Olive, Perennial rye, Date palm</td>
<td>Use micro-irrigation methods where possible. High leaching requirements may be required.</td>
</tr>
<tr>
<td>Tolerant</td>
<td>Couch grass, Sugar beet, Cotton, Barley (grain)</td>
<td>Do not wet leaves if possible. Excellent drainage and high leaching requirement necessary.</td>
</tr>
</tbody>
</table>

*The ranking assumes good drainage and appropriate cultural methods.

A number of biological and environmental factors affect crop salt tolerance.

Some varieties and rootstocks within some species are more tolerant of salt, and tolerances may also vary with growth stage. Fruit crops tend to be less salt tolerant as they become older, though it is more frequent for crops to be less tolerant at germination and emergence.

Hot and dry or waterlogged conditions can reduce the salt tolerance of many crops.

**Leaching fraction**

Most Western Australian waters used for irrigation are not saline enough to cause immediate harm except when leaf damage results from sprinkling sensitive crops during hot, dry conditions. Irrigation water adds salt to the soil and this is concentrated by evaporation removing the water and leaving the salt behind. To prevent too much salt accumulating around the plant roots, some water must percolate beyond the root zone and wash or leach salts from the soil. The proportion of the applied water that is available to leach salts from the root zone is called the leaching fraction.

The required leaching fraction (called leaching requirement) is additional to the crop’s water requirement and depends on the plant’s salt tolerance and the salinity of the water. The lower the salt tolerance and the higher the water salinity, the more leaching is needed to maintain satisfactory salt levels in the soil.

Where high leaching rates are needed water supplies and reticulation systems should be adequate to ensure the crop’s total water requirements can be met. Soil permeability must be high enough to allow the percolation of large amounts of water and drainage good enough to prevent the development of a shallow watertable.

Sufficient water to meet the leaching requirements can be applied with every watering or as periodic heavy applications. Rainfall during the irrigation season effectively leaches salts out of the plant root zone and allowance should be made for this. On well drained soils heavy winter rainfall will leach away accumulated salts and prevent a salt build-up from one irrigation season to the next.

Table 2 shows the leaching requirements to prevent yield losses of a number of crops being irrigated with waters of different salinities. Rainfall during the growing season will reduce leaching requirement in proportion to the effect it has on average salinity of the total water (rain plus irrigation) applied.

**Toxicity assessment**

The most common constituents of irrigation water that cause toxicity are sodium, chloride.

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*TOP: With all irrigated crops, careful water management means slightly saline water can by used.*

*ABOVE: Micro-sprinklers can be used for watering grape vines and other salt-sensitive plants.*
and boron. In Western Australia high sodium and chloride concentrations are common in both surface and bore waters, while high boron levels can be found in bore waters in the State's northern areas.

Many crops are sensitive to boron, with levels in irrigation water as low as one to two milligrams per litre causing toxicity symptoms. The symptoms first appear as a yellowing, spotting or drying on the tips and edges of the older leaves. The tissue drying-out can extend from the leaf tips and edges to the intersitial areas.

Tree crops and other woody perennials, in contrast to most annual crops, are sensitive to chlorine or sodium in the water. Tolerance of sodium and chloride varies with the type of crop grown, the variety and the rootstock used. The watering method used can also influence susceptibility to damage.

Citrus and stone fruits rapidly take up salts through the leaves. Water with as little as 100 mg/L of either sodium or chloride will cause damage if sprinkled on the leaves. These concentrations however will not cause salt damage on these crops when water is applied directly to the soil. Strawberries and avocados, though sensitive to salts in the soil, do not readily take up salt through the leaves and can be safely sprinkled. Grape vines are more sensitive to salts in the water and soil than the leaf tips and edges of the older leaves. The tissue drying-out can extend from the leaf tips and edges to the intersitial areas.

Increasing toxicity problems can be expected, irrespective of watering method, on susceptible crops with waters containing between 150 and 350 mg/L of sodium or chloride. Above 350 mg/L severe problems will occur.

Leaf symptoms and leaf tissue analyses can be used to diagnose sodium and chloride toxicity. Excessive leaf drop and burning, or scorching of the leaf tips and leaf margins of fruit crops, are good indicators of toxicity. Fruit crop leaves usually suffer from toxicity when the dried leaves contain more than 0.2 per cent sodium or 0.5 per cent chloride.

**Management and salinity control**

Management plays a vital role in handling water quality problems. Good cultural and watering practices that ensure high levels of production can produce a profitable crop even with marginal quality water. Good water and soil management to ensure adequate leaching will avoid salinity problems. If adequate leaching cannot be obtained then more salt tolerant crops should be grown.

Poorly drained soils or areas with watertables close to the surface should be avoided unless drainage can be justified. In areas with shallow watertables, salinity problems will occur even if low salinity water is used. Waterlogging from either rainfall or irrigation should be avoided as it reduces plant tolerance of salinity and toxicity.

<table>
<thead>
<tr>
<th>Potato yield (t/ha)</th>
<th>Irrigation water salinity Total soluble salts (mg/L)</th>
<th>Root zone soil salinity (ECe mS/m)</th>
<th>Total soluble salts (mg/L)</th>
<th>Root zone soil salinity (ECe mS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>37</td>
<td>220</td>
<td>180</td>
<td>220</td>
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<td>32</td>
<td>42</td>
<td>250</td>
<td>170</td>
<td>250</td>
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<td>57</td>
<td>340</td>
<td>120</td>
<td>340</td>
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<td>15</td>
<td>83</td>
<td>500</td>
<td>200</td>
<td>500</td>
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<td>21</td>
<td>150</td>
<td>900</td>
<td>300</td>
<td>900</td>
</tr>
<tr>
<td>29</td>
<td>216</td>
<td>1300</td>
<td>250</td>
<td>1300</td>
</tr>
<tr>
<td>30</td>
<td>400</td>
<td>2400</td>
<td>620</td>
<td>2400</td>
</tr>
</tbody>
</table>

If using sprinklers with saline or potentially toxic waters, avoid wetting the foliage. If this is not possible, water at night to avoid hot, dry and windy daytime conditions and use heavy droplet continuous wetting sprinklers to avoid salts concentrating on the leaf surface. With trickle irrigation frequently more saline water can be used because the soil is wetted more evenly.

It is possible to mix waters to reduce salinity and to treat them to prevent toxicity, sodicity and other problems, such as iron staining of floricultural crops.

More innovative methods of handling water salinity problems are emerging from overseas work. These recognise that crops are more sensitive to salt during establishment. Scarce fresh water is used during this stage and subsequent waterings can use more saline waters without causing yield losses. Follow-up crops with higher salt tolerance are planted to avoid problems caused by soil salt build-up under the previous crop. Eventually the salts have to be leached out, either by rainfall or a period of irrigation with fresh water. Overall much less of the scarcer, good quality water is used.

The various management options and strategies used frequently will have a cost and this should be compared with the benefits.

**Local potato yields**

Table 3 shows potato yields taken from a survey of growers in the Manjimup area and compares these to irrigation water salinity and the resultant soil salinity. Although there is a correlation between water salinity and soil salinity, there is none between water salinity and yield. Equal or superior yields have been obtained with the saltier waters. Potential yields of potatoes can be reduced by 20 per cent or more where soil salinity is more than 300 mS/m. By careful water and cultural management growers with salty water were able to counteract this potential yield loss and achieve yields as good as or better than growers with better quality water.

The message is clear. Within limits 'salty' water is better than no water as salinity is only one of the factors affecting crop growth. The farmer who knows his water salinity, the crop's tolerance of salinity and specific ion toxicities can select appropriate water management methods to give good yields.