water quality

for irrigation of citrus trees

In light of decreasing availability and quality of water used for irrigation of citrus in many regions of SA, producers are compelled to investigate the possibility of using new water sources.

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Given the questionable quality of alternative water sources, citrus producers are often unsure when it comes to adequately supplementing limited irrigation water supplies, or if these alternatives can be used for new developments. In this article the most common factors that determine whether water is suitable for irrigation and possible mitigation options are discussed.

Water salinity

The first quality parameter that must be considered is *total dissolved solids* (TDS), which measures the total quantity of various inorganic salts dissolved in water. The TDS is assessed by measuring the *electrical conductivity* (EC) of the water. The principle of EC measurement is based on the fact that salts in water increase the rate at which electricity is conducted in the water. Therefore, the TDS is typically calculated mathematically by laboratories from the EC by using a factor that will differ according to the unit in which the EC is expressed. The relevant factors are provided in Table 1 below, with the TDS being expressed as milligrams per litre (mg/ℓ), which is equal to parts per million (ppm).

Interpretation of the total salt content of water is done using a scale of EC values – the higher the EC, the less suitable the water becomes for citrus production. Different EC ranges are used to classify the water quality – the different classes that are internationally used as an indication of the suitability of the water for citrus production is provided in Table 2. The EC, however, does not indicate the type of salts that are present in the water.

The sodium content of the water

Even though the water's total salinity places it in salinity Class C1, C2 or C3, it can still be unsuitable for irrigation due to disproportionately high sodium (Na) in the water. In addition to being a salt that can damage plant tissues in extremely high concentrations, Na is harmful to soils since it displaces Ca and Mg on clay particles, resulting in clay dispersion and breakdown of soil structure. A decreased water infiltration and/or drainage, with an exponential increase in the soil salinification rate, is the end-result.

To evaluate the risk that Na poses to the soil, the ratio of Na in relation to calcium (Ca) and magnesium (Mg) in the water is used, being expressed as a factor called the sodium adsorption ratio (SAR). The SAR is a value that is mathematically calculated by the laboratory from the water Na, Ca and Mg analysis results. An interpretation of the SAR values is provided in Table 3.

Irrigation water analysis reports will therefore often contain a so-called irrigation class, which is expressed with C and S symbols denoting the salinity (C = conductivity) and sodium status (S = sodium). For example, highly saline water (EC > 2.25) with a low SAR (<5) will be classified as a C4S1 water. These classifications can be interpreted from tables 2 and 3.

Table 1. Conversion factors used to convert between the different units that are used to express water EC, as well as to convert EC to TDS

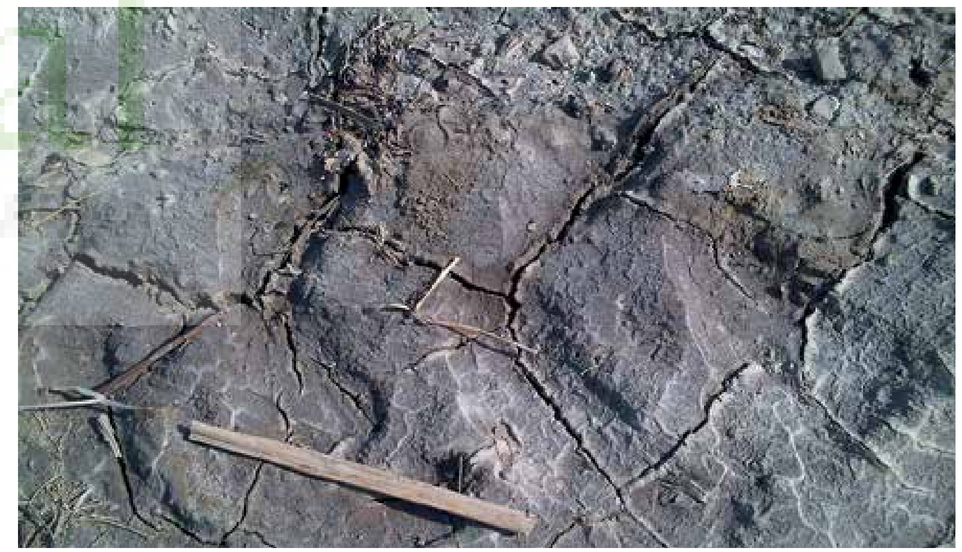
Unit		Factor for conversion	
		From mS/cm	To TDS
milliSiemens per cm	mS/cm	Reference unit	640
desiSiemens per meter	dS/m	mS/cm x 1	640
microSiemens per cm	µS/cm	mS/cm x 1000	0.64
milliSiemens per meter	mS/m	mS/cm x 100	6.4

Residual sodium carbonate index

When the pH of the irrigation water exceeds 8.0, a useful alternative measure of the risk that sodium poses is the *residual sodium carbonate* (RSC) index. In this index the bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations in the water are brought into consideration. The logic being that precipitation of soil Ca and Mg with HCO_3^- and CO_3^{2-} in the irrigation water subsequently leads to an increase in the relative proportions of sodium to the other cations in the soil solution. This situation, in turn, will increase the sodium hazard of the soil-water to a level greater than indicated by the SAR value of the irrigation water. Therefore, a high RSC of irrigation water results in an increase in the soil's *exchangeable sodium percentage* (ESP), with the consequent dispersion of clay, as referred to above.

Table 2. The EC ranges used to classify irrigation water quality - note the comments referring to suitability for citrus

EC (mS/cm)	Class (C)	Interpretation
0 - 0.25	1	Low salinity water – suitable for use on all soils.
0.25 - 0.75	2	Medium salinity water – poses few restrictions to citrus if leaching is possible.
0.75 - 2.25	3	High salinity water – cannot be used for citrus production on soil with poor drainage. Ensure good drainage, e.g. use only on sandy soils or soil with high Ca saturation that maintains soil structure.
2.25 - 5.5	4	Very high salinity water – cannot be used continuously for citrus production, even on well drained soils (soil with < 3 % clay).
>5.5	5	Extremely high salinity water – cannot be used for citrus production, even on an ad hoc basis.



Crust formation that typically occurs on the surface of soil that is irrigated with water that has a high residual sodium carbonate index or an excessive SAR. The result is poor water infiltration, i.e. excessive run-off

Table 3. Classification of the sodium status of irrigation water using the SAR

SAR	Sodium Status (S)	Interpretation
<5	1	Few, if any problems, except if water has very low EC and Ca is leached from the soil.
5-15	2	Increasing problems – the soil's exchangeable sodium percentage as well as salinity, must be monitored annually. Addition of Ca to the irrigation water, or application of gypsum to the soil might be required.
15-25	3	Almost unusable – if the water has a low EC (<0.75 mS/cm), Ca can be added (mostly in the form of gypsum) to improve the water.
>25	4	Unusable – serious problems with progressive deterioration of soil structure will result in exponential accumulation of salts in the soil.

On their own, high HCO_3^- and/or CO_3^{2-} levels in irrigation water also increase the water pH, cause clogging of irrigation systems due to calcite or lime deposition, and a whitish deposition forms on leaves and fruit from the droplets of irrigation water.

In arid and semi-arid regions, underground water often has a high pH and RSC. The higher the pH of the water, the higher the HCO_3^- - and CO_3^{2-} concentration will be, with a progressive shift towards CO_3^{2-} as the pH increases. Clogging of irrigation systems increases as the HCO_3^- and CO_3^{2-} concentration and water pH increase. The guidelines in Table 4 can be used to assess the risk of drip irrigation systems becoming blocked due to calcite/lime deposition.

To assess the risk of sodification of soil, a calculation of the RSC should be done if the HCO_3^- and CO_3^{2-} concentration of the water exceeds 120 mg/ℓ and 15 mg/ℓ respectively and the SAR>3. The RSC can be calculated from normal irrigation water analysis results, using the following formula:

$$RSC\ index = \{(HCO_3^-/61) + (CO_3/30)\} - \{(Ca/20) + (Mg/12)\},$$

where the concentrations are in mg/ℓ, and the resulting RSC index value is expressed in milli-equivalents per litre (meq/ℓ).

The following indicates the suitability of water for irrigation on account of the RSC index (meq/ℓ):

Safe to use on any soil	Marginal, with moderate risk on heavy clay soils	Not suitable for irrigation on any soil with > 5% clay
<1.25	1.25 - 2.50	>2.50

Table 4. Evaluation of concentrations of HCO_3^- and CO_3^{2-} to assess the risk of calcite/lime deposition causing blockage of drip irrigation lines

Sum of carbonates	Adequate for irrigation	Possible risk of clogging	Severe clogging
HCO_3^- + CO_3^{2-}	<150 mg/ℓ	150-300 mg/ℓ	>300 mg/ℓ

Drip irrigation lines become blocked when irrigation water with high bicarbonate and carbonate concentrations is used

Management and mitigation possibilities

From the above tables, it is implicit that while it is possible to use a wide variety of water quality types for irrigation, management procedures become more demanding as the water quality decreases – the suitable range of soils for citrus also becomes more restrictive. Possible management options to prevent build-up of salt in the soil, and ensure long-term tree performance, are:

Soil drainage: To avoid build-up of salts, the soil must be permeable – a permeable soil can be leached to wash out the salts. In this regard, sand is much more forgiving than heavy soil.

Leaching: Salt build-up in soil is avoided through leaching. Through regular monitoring of salt levels in the soil (measuring the soil's EC or resistance), the need for leaching (or its effectiveness when practiced) can be determined. Generally, the higher the salt level of the water, the more arid the climate, and the greater the leaching requirement will be.

Irrigation frequency and duration: Irrigation scheduling has a significant impact on salt accumulation or reducing levels in the soil. Short, regular cycles will more likely result in salt build-up in the topsoil because of evaporation. On the other hand, long cycles leading to deep water penetration mitigate build-up of salts in the root zone.

Soil and water amelioration: Irrigation water can be modified with gypsum to improve its SAR. The quantity of gypsum needed for adding to irrigation water depends on the quality of water (the SAR and RSC) and the annual quantity of water required for irrigation of the trees. The addition of gypsum increases water salinity, so this is only an option when the water's salinity is not too high, and when the soil is well drained. Soils can also be modified using gypsum to ensure proper drainage (it helps to maintain and improve the soil's structure), but this should only be used when the soil's exchangeable sodium percentage exceeds 10%. Otherwise the soil is actually further salinified.

In this article the three most important water quality parameters were discussed, i.e. total salinity, SAR and RSC. These are the most common restricting factors that must be considered. Water quality problems can also be associated with the presence of other constituents, like excessive levels of iron (Fe) or manganese (Mn), that can result in drip irrigation systems being blocked.

Literature cited

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Regarding water salinity, the first quality parameter that must be considered is total dissolved solids, which measures the total quantity of various inorganic salts dissolved in water.