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Desalination strategies for irrigated agriculture

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KwaZulu-Natal (KZN) farmers utilize water for irrigation, hydroponics and various other reasons. Suitability of water for irrigation is determined by the level of electric conductivity (EC) of water. Different classes of water have been defined according to their electric conductivity (Table1).

Table 1: Classification of irrigation water (Beltrán and Koo-Oshima 2006)

Water class	Electric conductivity (EC) (mS/m)
Non-saline	<70
Slightly saline	70-200
Moderately saline	200-1000
Highly saline	1000-2050
Very high saline	2000-4500
Brine	>4500

High levels of saline in irrigation water pose a serious water quality issue to KZN farmers (Mnkeni *et al.* 2010). Saline water contains increased concentrations of dissolves salts. Use of highly saline irrigation water causes a reduction in water availability to the crops, decreasing crop quality and crop yield. Other factors, including soil type, drainage and time of irrigation, affect the extent to which saline irrigation water may compromise crop quality. This update will assist KZN farmers with desalination strategies to improve water quality, and hence crop and pasture production, and to limit the damaging effects of salty soils (Zarzo *et al*. 2013, Kumar *et al*. 2017).

Sodium chloride, calcium and magnesium bicarbonate, chlorides and sulphates are common salts found in irrigation water. Studies show that sodium chloride is the most common soluble salt detected (Beltrán and Koo-Oshima, 2006), however this may vary depending on the water source.

Reduction of crop yield takes place before apparent visual symptoms of salinity damage. Stunted growth of crops is the first sign of excess salinity, with leaves often having a bluish-green colour. Increasing salt concentration in soil promotes scalding or burning on the edges and tips of the older leaves. This results in the leaves dying and finally falling off. In some cases young leaves appear to be yellow, or crops show signs of wilting, even when the soil is adequately moist. Crop growth can be affected by both salinity and toxicity effects.

FIGURE 1. Irrigation with saline water can reduce crop quality and yield (Photo: Prince, 2019)

Salinity effects

Plant roots use root cell membranes to take up moisture in a process called osmosis. Irrigation water with low levels of dissolved salts passes through a semi-permeable membrane. This process continues until the plant roots becomes full of moisture. Plant roots work harder to take up water from the soil when irrigation water contains increasing levels of dissolved salts. This slows down growth, thus reducing crop yields.

When highly saline irrigation water is used, the process of reverse osmosis takes place. This is when the plant roots are exposed to a solution of higher salt concentration than that within the root cells, resulting in water moving from the roots into the surrounding solution. At this stage, the plant loses moisture and growth is affected.

Toxicity effects

High levels of sodium and chloride ions in irrigation water leads to chemical toxicities that can be hazardous to plants. These ions are taken up by plant roots or through direct contact on the leaves. More damage is caused by direct absorption through the leaves.

- ### Sodium

Leaf burn, scorch and dead tissues along the outside edges of the leaves are typical symptoms of sodium toxicity. In soils low in calcium (Ca) and potassium (K), high concentrations of sodium in irrigation water induce plant Ca and K deficiencies, thus crops that have been irrigated with saline water often respond to fertilization with these nutrients. The sodium absorption ratio (SAR) of the irrigation water is a measure of the relative percentage of sodium ions to calcium and magnesium ions in water. A <3 SAR indicates low levels of sodium, 3-9 SAR indicate slightly high levels and >9 indicate high levels of sodium relative to calcium and magnesium (Aboukarima, Al-Sulaiman and El Marazky 2018). A high SAR indicates an accumulation of sodium in the soil, which the soil structure by breaking down clay aggregates resulting in, waterlogging and poor plant growth.

- ### Chloride

Chloride ions get taken up by plant roots and accumulate in the leaves. Excessive accumulation in the leaves causes burning of the leaf margins or tips, bronzing and premature yellowing of the leaves. Studies show that most fruit trees are sensitive to chlorides, whereas forages, most fibre crops and vegetables are less sensitive. This makes the analytical quantification of chlorides and sodium concentrations in water a vital step prior to irrigation of agriculture.

Desalination strategies

Costly strategies

- ### Thermal distillation

This process simulates the natural process of producing rain. Saline water is heated, producing vaporized water molecules that in turn condense to freshwater, thus producing pure water by distillation. This process may be achieved by multi stage flash (MSF) distillation, multiple-effect (MED) distillation or vapour compression (VC) distillation.

- ### Membrane processes

I. **Electro-dialysis (ED)** - a membrane process whereby salts are separated from water by means of an electric load application.

II. **Reverse osmosis (RO)** - a membrane process in which pressure is applied to the intake water to force it to flow through a semi-permeable membrane (filter) that prevents salts from passing through. For agricultural uses, RO is the preferred desalination technology because of the cost reductions driven by improvements in membranes (filters) in recent years and is a very convenient strategy compared to other methods (Miller 2003; Miller and Evans 2006).

More economically-viable strategies

- ### Solar energy desalination

The use of use ultraviolet irradiation is a high-intensity method that uses broad spectrum ultraviolet irradiation to remove chlorine by dissociating free chlorine and turning it into hydrochloric acid. However, this process produces only a small amount of pure water (Tikkanen *et al*. 2001).

- Leaching soluble salt from soil with good quality water.
- Digging dip trenches and collecting rain water into saline water and mix them.
- Usage of good quality water during germination and establishment stage and use saline water at later stage of growth.
- Choosing crops for cultivation, based on the salinity of the place and salt tolerance of the crop.

Conclusions

Many factors affect freshwater availability for KZN irrigated agriculture, such as changes in annual rainfall as a result of climate change. This may lead to a shortage of water and hence decreased crop yields for KZN communities. Consideration of desalination strategies is imperative to increase the quality water supply for irrigated agriculture when rainfall is restricted.

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