Information Sheet

5.11 Properties of saline/sodic soils and their reclamation

Introduction

Sugarcane is moderately sensitive to salinity (excessive build-up of plant essential salts), compared to tolerant crops such as barley, oats, cotton and sugar beet. Sugarcane is also sensitive to sodicity (a dominance of sodium salt). Excess salts affect the environment housing roots. To function optimally in support of the plant, roots need unrestricted access to nutrients, water and air. Therefore, excessive salt loads in soils will negatively affect sugarcane yields.

Salt affected soils and rivers are confined mainly to those areas of the sugar industry receiving a mean annual rainfall of less than 760 mm, i.e. the Mpumalanga and Swaziland Lowveld, Pongola and river valley regions such as Nkwalini and Heatonville. Serious problems occur mainly on the poorly drained, highly dispersed grey soils derived from Beaufort sediments, Dwyka tillite and Vryheid sediments, and black swelling clays derived from basalt, dolerite and Pietermaritzburg shales as well as Vryheid shales.

Types of salt affected soils

There are two types of salt-affected soils: saline soils and sodic soils.

Salinity (also termed “wit brak”) is a condition caused by plant essential salts such as calcium, magnesium and potassium which will make it difficult for plants to extract water (due to osmotic stress) when present in excessive amounts. Although the soil might be wet, the crop will show signs of wilting on a hot and windy day, followed by scorching of the leaves, restricted growth and stool death in severe cases (Figure 1).

Soil parameters used as indicators of salinity are:

- Electrical conductivity (EC);
- Sodium Adsorption Ratio (SAR); and Soil pH.

Figure 1: Salinity of the soil in the foreground was too high for sugarcane to survive.

Sodicity (also termed “swart brak” or “black alkali”) is a situation where sodium, a nonessential salt, is dominant relative to the saline salts and will cause soil structure to collapse (dispersion, Figure 2), toxicity in plants (Figure 3) and death in severe cases. Dispersion of the soil at the surface will lead to reduced air exchange leading to a build-up of toxic gasses in the soil. It will also reduce water infiltration rates, leading to frequent run-off, and erosion in severe cases.

Soil parameters used to identify sodicity are:

- Exchangeable sodium percentage (ESP),
- Sodium adsorption ratio (SAR); and
- pH.

Soil with a combination of both salts is known as saline-sodic soil (Table 1). Due to the high salinity component, plants may experience light degrees of wilting on hot and windy days. Water passage to facilitate leaching is restricted in soils with collapsed structure and thus might stop in severe cases. Since sodium is present in sufficient quantities, it will lead to early stages of structural collapse. If soil structure is not yet affected, then these salts can be leached with water provided the soil has excellent drainage properties or are artificially drained.

Table 1. Categories and properties of saline and sodic soils.

Category type	Electrical conductivity (mS/m)	SAR (ESP)	Dominant cation(s)	pH(water)	Effect on soil structure
Normal	<400	<6 (<7)	None	<8.5	None
Saline	>400	<6 (<7)	Mainly Ca and Mg	<8.5	None (osmotic interference of plant uptake of water)
Saline-sodic	>400	>6 (>7)	Ca Mg and Na	<8.5	Early stages of dispersion
Sodic	<400	>6 (>7)	Mainly Na	>8.5	Severe dispersion and possible Na toxicity

▲ Figure 2. Sodic "Swart brak" soils where sodium salt is dominant, the pH is greater than 8.4 and the soil is in an advanced dispersed condition.

▲ Figure 3. Death of sugarcane over a large area due to sodium chloride toxification following flooding of the area by sea water.

Causes of salt build-up in soils

Salts are either native to soil (coming from the parent material) or are imported through seepage, irrigation water or rainfall. The rise and fall of a water table is an important mechanism along with capillary rise of water bringing salts (particularly sodium chloride) dissolved in the groundwater to the surface, causing patches of saline-sodic or sodic soil. Rain of 800 mm/year received up to 30 km from the coast could add 130 kg/ha Na. Sugarcane takes up less than 10 kg/ha Na per crop. The remainder will accumulate in the soil if the soil is poorly drained.

The accumulation of salts from all these sources usually takes many years to manifest, as was the case in the Pongola Irrigation Scheme, where serious problems only appeared after 40 years of continuous cane production. Once excessive salts in soils become visible on the surface, the size of the affected area will grow rapidly. Salinisation (mainly due to Ca and Mg salts) tends to be more prevalent in severe drought years (due to osmotic pressure adding to water stress).

Salinity

Electrical conductivity (EC, measured in milli-siemens per metre or mS/m) is a measure of the total soluble salts in the soil solution. The salinity rating of a soil profile is based on the mean EC value for depths 0 - 30 cm, 30 - 60 cm and 60 - 90 cm. Table 2 indicates how sugarcane growth is affected by increasing soil EC values. The effects of salinity on sugarcane can be influenced by factors such as clay content, drainage properties of the soil, irrigation water quality, and the sugarcane variety (drought-tolerant varieties are also tolerant to salinity).

Table 2: Effect of exchangeable sodium percentage and electrical conductivity of soils on the growth of sugarcane (modified after Von der Meden, 1966).

Exchangeable sodium percentage (ESP)	Electrical conductivity (mS/m) in top 450 mm soil depth	Effect on sugarcane growth
< 6	< 200	Not affected
6 – 10	200 – 400	Growth is reduced
10 – 15	400 – 600	Yields severely affected
> 15	> 600	Yields very severely affected

Note: The threshold value for SAR is 6 and that for ESP is 7. For practical purposes, the same value can be used for both.

Sodicity

The mean sodium adsorption ratio (SAR, the proportion of sodium to calcium plus magnesium) for depths 0 - 30 cm, 30 - 60 cm and 60 - 90 cm are used as an index of sodicity. Exchangeable sodium percentage (ESP) is another measure of sodicity and is an indication of the coverage of clay particles by sodium. When the measured SAR or ESP value is greater than the threshold value (see Table 2), the soil is rated as being sodic.

Impact of salinity and sodicity on stalk yield

Electrical conductivity (EC) is a measure of the concentration of the mixture of salts in soils. It is, however, used as an indicator of salinity. See Table 2 for EC threshold values and their impact on sugarcane growth. Sugarcane stalk yield is lowered by between 14 per cent and 16 per cent for every one unit increase in the electrical conductivity of the saturated extract (ECe) above the threshold of 170 mS.m. This is very similar to stalk losses that can be expected due to a sodicity condition in soils. Expressed as ESP, stalk yield is reduced by 2 tons/ha for every 1% increase of ESP above the threshold value of 7. However, stalk yield loss due to sodicity can be as high as 10 tons/ha for every 1% increase in ESP. These losses can be avoided if the condition of the soil is monitored, and actions are taken before the soil becomes saline or sodic.

Assessing the salinity/sodicity status of the soil

To determine the salt status of soils, samples should be taken from a few places where sugarcane growth is normal and where it is affected. Sampling depths should be 0 - 30 cm, 30 - 60 cm and 60 - 90 cm. The purpose of taking samples from these depths is to enable FAS to comment meaningfully regarding the origin of the salt problem and to give appropriate advice to manage the problem. Generally higher values at the bottom indicate that the source of salts is probably the parent material or seepage water while higher values at the surface indicate that the water used for irrigation is probably the source of salts. Measurements that will be conducted in the laboratory include pH, SAR, ESP, EC, Ca, Mg and Na (measured in the extract from a saturated paste). See Tables 1 and 2 for the interpretation of these parameters on soils and sugarcane growth.

Reclamation of salt-affected soils

Saline, saline/sodic and sodic soils can be successfully reclaimed and converted into highly productive soils. Depending on the condition of the soil, this could potentially be an expensive, difficult and time-consuming operation. For this reason, a policy of 'prevention is better than cure' should be adopted from the outset.

To achieve this, the following is recommended:

- Know the salt load of your irrigation water and how it changes from summer to winter.
- Know the salt load in your soil.
- Know the tolerance of your crop to salinity and sodicity.
- Ensure adequate surface and subsurface drainage as it is essential to permit effective leaching of accumulated salts from the soil.

Reclamation of saline soils

Saline condition is relatively easy to solve with the following procedure:

- Ensure that the soil is adequately drained. Contact your Extension Specialist for advice.

- To reclaim a saline soil (high in essential salts, low in sodium), salts must be leached out using heavy applications of irrigation water (apply at least 40 mm weekly where possible) of acceptable quality. The application of chemicals such as gypsum or sulphur is not required.

Reclamation of saline/sodic and sodic soils

Reclamation of Na affected soils is expensive and requires time and good management. The following is a guide to the reclamation of sodic soils, but growers are advised to consult their Extension Specialists before any action is taken:

- Ensure that the soil is adequately drained. This is very important.

- Since these soils are normally dispersed and water infiltration rates significantly reduced, high amounts of organic matter (i.e. > 100 t/ha filter cake) should be incorporated to improve soil structure to facilitate water infiltration and leaching.

- To reclaim a sodic soil, also apply gypsum at 5-10 tons/ha (or the amount recommended by FAS) to promote replacement of sodium on the clay particles by calcium, and to improve soil structure. Consideration should also be given to acidify the soil using elemental sulphur, for instance, at 6 tons/ha.

- Since sodic soils are normally highly dispersed and therefore slowly permeable, the ameliorants should be incorporated as deeply as possible (300 mm) and thoroughly mixed with the soil through cross ploughing or discing to improve the rate of sodium's replacement by calcium and its leaching from the soil profile. If the slope of the field is greater than 2%, then select a dry period with no rain for this process to minimise the risk of soil losses through erosion.

- Following the application of ameliorants, the soil must be leached with heavy applications of water provided the soil's drainage system is effective. To dissolve gypsum, the general guideline is to apply 100 mm irrigation water (or sum of irrigation and rain) for every ton of gypsum applied. Apply about 40 mm of irrigation every week to facilitate leaching of unwanted salts.

- Quality of water used for reclamation must not be too pure at the start. Clean water of a very good quality will result in a collapse of structure due to expansion of the sodium molecule causing dispersion and sealing, preventing water from entering soil. See Table 3 as a guide for the quality of irrigation water to be used in the reclamation of sodic soils. Should the EC of water to be used for reclamation be too low, add gypsum to the water to raise the EC. This should not be necessary for fields with sandy soils.

- Plant crops to assist with Na removal and to cover the surface for added protection against erosion. Crops to consider are oats and ryegrass in winter and barley, sorghum, sunflower, cotton, sesame and cauliflower in summer. When crops are harvested, all residue must be removed from the field to avoid recycling of the salt.

Table 3: Guidelines for assessment of sodium hazard on the infiltration rate of irrigation water based on SAR and ECw, when applied to soils containing more than 30% clay.

Water quality in terms of sodicity (SAR) and salinity (ECw)	Infiltration rate limitation (mS/m)		
	Severe	Moderate	None
When SAR = 0 - 3 and ECw (mS/m) =	< 20	20 - 70	>70
When SAR = 3 - 6 and ECw (mS/m) =	< 30	30 - 120	> 120
When SAR = 6 - 12 and ECw (mS/m) =	< 50	50 - 190	> 190
When SAR = 12 - 20 and ECw (mS/m) =	< 130	130 - 290	> 290
When SAR = 20 - 40 and ECw (mS/m) =	< 290	290 - 500	>500

ECw = Electrical conductivity of the water (Modified from Miller and Gardiner, 2007).

The importance of assessing salinity/sodicity in irrigation water

It is vital to assess irrigation water for quality (salt load). Ideally, water samples should be collected every season to account for the difference in salt load over the year. Water samples must be submitted to an analytical lab such as SASRI's Fertiliser Agricultural Laboratory (FAS) to analyse them for pH, SAR and EC. However, it is important to note that the SAR and EC values will need to be corrected to facilitate meaningful interpretation of the effect of the water on soil quality. To do this, bicarbonates in the water sample is taken into account because it will remove Ca from the soil resulting in an increased soil SAR value. Additionally, the dilution effect of regional rainfall on EC values (EC is an indication of the total salt load in the water sample) is taken into account to calculate effective EC (EEC). It is thus important to supply the regional annual rainfall value when water samples are submitted for quality assessment.

See Information Sheet 5.12: Water quality for Soil Health for details on assessing and interpreting irrigation water quality and the FAS report guides on how to read a salinity/sodicity report and water quality report (https://sasri.org.za/crop-nutrition/).

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