Information Sheet

6.7 Management of high pH (alkaline) soils

Sugarcane has a very wide tolerance of soil pH, growing well in acidic to alkaline soils. While much emphasis is given to ameliorating low pH (acidic) soils in the rainfed regions of the South African sugarcane industry, many of the irrigated soils in the more arid regions have soil pH values > 6.5, and in some extreme cases (sodic soils) can be as high as 8.5. At these higher pH values, there is an increasing risk of a decline in sugarcane yield, this often associated with reduced nutrient availability (mainly phosphorus (P) and micronutrients) and increased risk of nitrogen volatilisation (mostly associated with urea application). Depending on the cause or nature of the alkalinity there may also be problems with soil structural stability, and competition between uptake of plant nutrients (such as calcium (Ca) and potassium (K)).

This information sheet briefly outlines the main types of high pH soils, the potential impacts of these and the management options to mitigate these impacts.

Cause of high pH soils

There are three main reasons for the development of soils with high pH:

1) Base-rich soils formed over base-rich parent materials with limited weathering (pH ranging from 6 to 8.3). Calcareous soil types (those with high amounts of free calcium carbonate and that are not sodic) typically have pH values between 7.5 and 8.3 (but not higher).
2) Sodic soils (pH typically >8).
3) Over-liming or excessive use of high-pH ameliorants of non-alkaline and unbuffered soils (pH > 6.5).

Soils that formed in the arid regions of the sugar growing region in South Africa (mainly Malelane, Komatipoort, Pongola, Mkuze and other localised areas) are typified by neutral to high pH, with high levels of calcium (Ca) and magnesium (Mg). They usually occur over base-rich parent materials, tend to have high clay content and are dominated by poorly weathered clay minerals due to limited leaching (and often are strongly structured). These soils are generally also more susceptible to the development of sodic (excess sodium (Na)), saline (excess salts) and magnesic (excess Mg) conditions under poor irrigation management. Alkaline conditions can also develop in sandy soils where alkaline parent materials influence their development or where poor management practices lead to the build-up of alkalinity.

Sodic soils are associated with poor soil structure, soil sealing and loss of porosity caused by excess Na in the soil. While excessively high pH and excess Na can lead to several nutrient related problems, loss of productivity in these soils are often more closely associated with the poor soil physical condition. The causes, impacts and remediation of sodic soils are discussed in Information Sheet 5.11: Properties of saline/sodic soils and their reclamation and 5.12: Managing water quality for soil health.

Over-limed soils reflect an excessive elevation of the soil pH due to the over application of lime or other alkaline ameliorants (such as high rates of lime enriched filtercake). Localised high pH may also occur where banded liming occurs. This effect may be extreme where strongly caustic liming materials are used (e.g. slaked or burnt limes). While the consequence of excessive liming tends to be reversible over time, the short-term consequence may be similar to those in more naturally occurring high pH soils. Sandy soils are more prone to over liming due to the lack of buffering.

Classifying high pH soils

While there are several factors to consider when managing high pH soils, and site-specific conditions will affect the decisions made, the table below provides a general guide to classify high pH soil:

Description	pH[1] ($CaCl_2$)	pH[1] (water)	Comment
Non-alkaline	< 5.5	< 6	Typical of rainfed regions. At pH < 4.5 acidity may become problematic.
Slightly acidic to neutral	5.5 – 6.5	6 - 7	Nutrient availability not greatly reduced, though early signs of P and micronutrient deficiency may occur in young crops at the higher pH and depending on soil properties.
Neutral to slightly alkaline	6.5 – 7.0	7 – 7.5	P and micronutrient deficiencies are likely to occur in early growth stages where nutrient levels are more marginal. These soils may be naturally high pH (due to parent materials and limited weathering) or be an indication that poor irrigation management and poor water quality are leading to alkalisation (associated with the development of sodic conditions).
Slightly to moderately alkaline	7.0 – 8.0	7.5 – 8.5	Nutrient deficiencies are likely. High pH is often associated with the early development of sodic conditions, so it is important to monitor sodicity indicators. Strongly calcareous soils (contain free calcium carbonate) may also exhibit high pH values in this range.
Moderately to strongly alkaline	8 - 9	8.5 – 9.5	Indicative of the development of sodic conditions. Organic matter will dissolve, soil structure may be severely compromised, and nutrient availability greatly reduced.
Extremely alkaline	>9	>9.5	Not common but may occur in localised areas where high rates of burnt or slaked lime and other caustic amendments are applied. At these high pH values organic matter will readily dissolve and soil structure can be compromised. Crop growth will be severely negatively affected.

[1] The relationship between pH($CaCl_2$) and pH(water) is approximate where pH water is typically between 0.5 and 0.75 pH units higher pH($CaCl_2$)

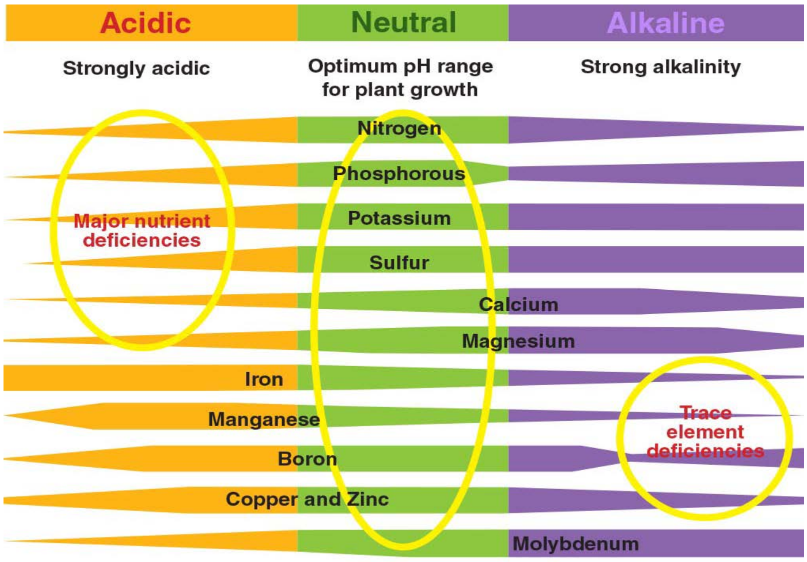
Beyond considering soil pH, other variables to consider include Ca and Mg levels, sodicity indicators, clay content and nutrient status of the soil. These parameters will provide supporting information to guide suitable management practices to remedy or mitigate negative impacts.

Impact of high pH soils

There are four main concerns associated with high pH soils:

1) Reduced plant availability of phosphorus and micronutrients (notably zinc, iron and manganese).

Optimal nutrient availability for crop production is typically in the pH range of 4.5 to 6.5 (see figure below). Visual symptoms in the crop generally relate to nutrient deficiencies, thus leaf testing is a useful tool to assess specific problems (see relevant Information Sheets 7.8 -7.12 for element specific symptoms and 7.15: Sugarcane leaf sampling for further guidance).



▲ At high pH, nutrient deficiencies may become crop limiting.

2) Volatilisation (gaseous) losses of nitrogen (N).

At pH >7, ammonium is converted to ammonia gas and can be lost to the atmosphere. This effect is often most notable in urea N sources that are not incorporated into the soil.

3) Nutrient imbalances caused by excessively high Ca and Mg levels.

Alkaline soils, particularly naturally occurring forms, tend to have higher amounts of both total and plant available Ca and Mg levels. Where plant available Ca and Mg levels are very high, K uptake may be reduced, and higher K fertiliser application rates are advised on these soils. In addition to amounts of Ca and Mg, the ratio of Ca:Mg is also considered, where preferably this should be >1. Where Mg becomes dominant, particularly in high pH and high clay soils, both physical problems and nutrient deficiencies can occur (See Information Sheet 6.8 Management of magnesium-rich soils).

4) Soil structural decline where the high pH is associated with either sodic or magnesic conditions.

In sodic (and possibly magnesic) soils the effect of high soil pH on nutrient availability can be made worse due to poor soil aeration and infiltration that has negative effects on root growth. This will further limit the ability of the crop to take up nutrients. It is necessary to monitor other key indicators of sodicity and salinity (such as exchangeable sodium percentage, sodium adsorption ratio and electrical conductivity) for accurate classification and management of the condition. Similarly, compaction and water logging also reduce root growth, thus further contributing to poor nutrient uptake.

Managing nutrients in high pH soils

The selected management of nutrients will depend largely on the cause and extent of the high pH in a soil. In naturally occurring high pH soils, it is difficult to lower the pH of the entire profile. In these cases, it is often better to adopt practices that improve soil conditions and nutrient availability around the root zone. For information on specific nutrients see Information Sheets 7.1 to 7.12, though the following additional strategies can be considered for high pH soils:

- Follow the recommended nutrient application rates provide by SASRI as these take soil properties into account.
- Where possible, make use of strongly acidifying ammonium-N fertilisers (such as ammonium sulphate) and adopt banded applications around the root zone. Preferably avoid using urea as an N-source where pH is >7.
- Where urea is to be used, ensure it is either irrigated into the soil or incorporated within two days of application. Where this is not possible, split applications will lower the risk of volatilisation losses and improve nutrient use efficiency in the crop. Avoid banding of urea.

- Band apply P and micronutrients near the cane sett during planting and avoid broadcast topdressing of these nutrients. In ratoons it may be necessary to knife P to improve availability for crop uptake.
- Where possible, apply organic sources of P (e.g. manures and chicken litter) or co-apply P fertiliser with organic materials, this reduces the formation of plant unavailable P-minerals in the soil.
- Drip fertigation is an effective method to introduce nutrients, especially P and micronutrients, to the active root zone. Metal chelates are reported to be more effective in alkaline soils. Ensure compatibility of nutrients in the mixing tank.
- If excessively alkaline irrigation water (pH > 7.5) is being used, consider acid treatment to lower pH to acceptable levels and to avoid additional alkalinity build-up in the soil.
- Where micro-nutrient deficiencies present themselves in the growing crop, then foliar application should be considered. See relevant Information Sheets 7.8 -7.12 for element specific recommendations.
- Apply acidifying ameliorants (e.g. elemental sulphur, sulphides) in bands below the cane setts (but not in contact with) during planting. This provides a longer-term localised acidification in the root zone area. Typical application rates range from 500 to 1000 kg/ha depending on the level of alkalinity and acidifying ameliorant. Applying higher rates can lead to salinity problems and damage to setts and roots.

Precautionary notes

- DO NOT attempt to acidify the entire affected area or soil profile of naturally high pH soils. This is almost impossible to achieve and requires vast amounts of acidifying materials. It is seldom an effective strategy and can lead to other problems such as salinity when excessive carbonate salts dissolve.
- Handle acidifying ameliorants with caution as they generate strong acids that can be harmful to operators and equipment.
- DO NOT apply lime to balance cation ratios – this is ineffective and will not ameliorate the impacts of the high pH condition.

In sodic soils, remedial action must be taken to lower Na levels as this will lead to an immediate reduction in pH (see Information Sheet 5.11). The strategies given above can also be used to improve short-term nutrient availability once the sodic condition has been treated.

Where soil pH is due to over liming, further lime (or alkaline ameliorant) application be stopped until soil pH returns to more favourable levels. The use of acidifying N fertilisers will promote this process. In severe cases, it may be necessary to adopt some of the strategies given for naturally occurring high pH soils to improve nutrient use efficiency until more acceptable pH values are achieved.

Louis Titshall (Senior Soil Scientist)

July 2022