Information Sheet

6.8 Management of magnesium-rich (magnesic) soils

Magnesium (Mg) is an essential plant nutrient, and generally, concerns relate to deficiency (especially in acidic soils) rather than excess levels. However, where magnesium levels are high (particularly in relation to calcium (Ca)), then soil structural and nutrient balance problems may occur. Magnesium-rich soils are referred to as magnesic soils. They may occur naturally or may develop due to the application of Mg-rich irrigation water. Magnesic soils tend to have unfavourable physical characteristics and are often referred to as being heavy, sticky soils, this in reference to the difficulties in working with such soils when moist. These soils can also lead to nutrient imbalances in the crop.

To ensure that magnesic soils are properly managed it is necessary to correctly identify their occurrence. Often growers are given inappropriate advice based on poor classification or understanding of this condition, leading to unnecessary applications of lime or other non-beneficial ameliorants. This information sheet outlines the occurrence, characteristics and suggested mitigation and remedial practices to improve such soils for better sugarcane production.

Occurrence or magnesic soils

The distribution of magnesic soils has not been extensively investigated, this partly due to the lack of a definitive classification system and the understanding of impacts. In the South African sugarcane growing areas, magnesic soils are most commonly associated with Mg-rich parent materials found near Malelane (Magnesite). The parent material in this region consists of minerals that contain proportionately higher Mg than Ca that lead to the development of magnesic soils. Magnesic conditions may also develop in other irrigated regions, particularly where irrigation water has high Mg content.

In rare instances, magnesic soils have been detected in the rainfed regions, these cases linked to inappropriate use of Mg-rich ameliorants and differential removal of Ca and Mg in some soil types.

Impacts of magnesic soils

The two main impacts are:

1) **Soil structural decline**

Where Mg is both in excess relative to Ca and at sufficiently high levels, the main impact is on soil structure, particularly on high clay soils. In a process similar to the effect of excess sodium (Na) in the soil, high Mg can lead to partial dispersion and structural collapse of soil aggregates. Magnesic soils are often referred to as being heavy and sticky and are difficult to work when wet. These soils dry to form hard clods. The permeability (infiltration and drainage) of these soils are generally low, and they may be more susceptible to compaction effects. The effect can be made worse under high pH (alkaline) conditions.

In cases where a soil has excess Mg relative to Ca (high exchangeable Mg percentage (EMP), but the levels of Ca and Mg are very low (sub-optimal), the impact on soil structure is generally of little concern. Where magnesic conditions develop in sandy soils, there is also often no noticeable impact on structure, due to the lack of reactive clays. In both these situations the impact tends to be related to nutrient imbalances (see point 2).

2) **Nutrient imbalances**

Excess Mg can interfere with the uptake of Ca, potassium, micronutrients and phosphorus leading to deficiencies or imbalances. Often magnesic soils are also associated with high pH, thus further contributing to the deficiencies (see Information Sheet 6.7 Management of high pH soils).

Some studies suggest that, at very high Mg levels, toxicity may occur in plants, though it is rare to observe specific Mg effects, but rather the deficiencies in other nutrients. In some crops it is reported that a coppery colour develops on leaf margins, this spreading to the entire leaf with eventual leaf drop as Mg levels increase. It is also reported that root formation is negatively affected.

Classifying magnesic soils

To date, no definitive criteria have been developed to classify magnesic soils, with several different approaches used around the world. This is because the effect of Mg in the soil is related to the total and exchangeable amounts in the soil, the proportion to mainly calcium (Ca), but also sodium (Na) and potassium (K), the soil clay amount and type and soil pH. However, it is useful to define a baseline criteria against which possible management practices can be considered. There are presently two main classifications approaches used:

Exchangeable Ca:Mg ratio (Ca/Mg)

The Ca:Mg ratio is calculated as the charge concentration of Ca divided by the charge concentration of Mg (Ca/Mg). In general, an exchangeable Ca:Mg ratio of greater than 1 (>1) is recommended (typical preferred range between 1 and 5) for sugarcane production. Ratios of <1 indicate more reactive Mg is present in the soil relative to Ca and thus a magnesic condition may be developing or is present. Where Ca:Mg is less than 1 (<1) there is an excess of Mg relative to Ca which can lead nutrient imbalances occurring, where excess Mg can inhibit the uptake of Ca. The following approximate classes are used:

Class	Exchangeable Ca:Mg ratio	Comment
Normal (non-magnesic)	>1	No soil structural problems expected though it is essential that adequate amounts are present to avoid nutrient deficiencies.
Slightly magnesic	0.5 - 1	Nutrient imbalance likely to start occurring, with evidence of negative impacts on soil structural properties (difficult to work when wet, setting hard when dry).
Magnesic	0.1 – 0.3	Stronger occurrence of above symptoms.
Very magnesic	<0.1	Severe soil degradation leading to poor infiltration and drainage, difficulty to till, and extreme hard setting when dry. Nutrient imbalance highly likely but soil degradation expected to have dominant impact on crop growth.

Exchangeable Mg percentage (EMP)

This is similar to the exchangeable sodium percentage (or ESP) used in sodicity assessment and relates the amount of exchangeable Mg to the sum of base cations (EMP = [Mg/(Ca +Mg + K + Na)] x 100), calculated on a concentration charge basis and expressed as a percentage:

Class	Exchangeable Mg % (EMP)	Comment
Non-magnesic	< 25	No structural problems expected.
Normal to slightly magnesic	25 - 40	Initial indications of development of "heavy" soils, that are difficult to work when wet and hard-setting when dry. More noticeable on higher clay soils. Depending on amounts, nutrients balances may also become apparent.
Magnesic	40 - 80	Stronger occurrence of above symptoms, with potential for severe structural degradation and nutrient imbalances with increasing EMP. Crop growth will likely be negatively affected.

Very magnesic	> 80	Likely that there will be severe structural problems in the soil with extreme nutrient imbalances. Crop growth will be severely reduced or stunted.

An adaptation of the EMP criteria adjusts the classification above based on the concentration of exchangeable Mg, where at low Mg levels (regardless of the EMP level), the soil is considered non-magnesic, but rather Mg-deficient. At very low Mg levels, even if proportionately high relative to Ca (leading to an elevated EMP), it is unlikely to have a noticeable negative impact on soil structure. However, nutrient deficiencies are possible and will need to be addressed. This situation is likely to occur on acidic soils where Ca and Mg levels have declined to suboptimal levels. It is not expected in the base-rich soils of the irrigated arid regions.

In the absence of more definitive criteria and conditions against which to assess magnesic soils (where sodic conditions are not dominant) it is advised that a combination of observed impacts on soil structure and crop growth, along with soil test measures be used to gauge the extent that the soil is magnesic. General guidelines that suggest the development or occurrence of a magnesic soil include:

- The Ca:Mg <1 and in more severe conditions <0.5.
- The EMP >40%.
- Exchangeable Ca and Mg levels adequate (>300 and >50 mg/L for sugarcane, respectively).
- Clay soils exhibit heavy and sticky behaviour when wet, with low permeability and infiltration.
- The soil forms very hard clods when dry.
- There are indications of nutrient imbalance in the crop, particularly related to Ca deficiency, despite adequate soil test values.

Important additional note on soil sodicity:
Sodic soils may exhibit similar symptoms to those of magnesic soils, so it is important to test your soils to permit a more conclusive determination of the cause of soil structural decline. Sodic and magnesic conditions may also occur together though the effect of a sodic conditions on soil structure is generally more pronounced than a magnesic condition.

Managing magnesic soils

Like for sodic soil conditions, the application of soluble sources of Ca (mainly as gypsum or phosphogypsum) to improve the Ca:Mg ratios and improve soil structure is advised. Additionally, the incorporation of organic matter will help open heavy, sticky soils, thus improving infiltration and water movement, as well as root growth of the crop. However, the success of the selected management of a magnesic soil depends to some extent on the specific conditions associated with the development of the high Mg status soil. For site-specific guidelines it is advised to consult with your regional Extension Specialist or Agronomic Advisor.

In naturally occurring magnesic soils that developed from Mg-rich parent materials, elevated Mg levels are likely to be present through the entire soil profile. In these instances, it is difficult to apply enough soluble Ca (e.g. gypsum) to successfully alter the Ca:Mg ratio to >1. In these soils it is often only feasible to improve conditions in the active root zone. In plant crops, the application of gypsum as bands over the intended row area to be planted (with incorporation) is suggested. Rates equivalent to between 2.5 to 10 t/ha (scaled to the row area to be treated) are usually recommended. Regular follow-up testing it required to check that sufficient Ca is being introduced and that there are no adverse consequences of high gypsum rates on salt loads. In established crops, top-dressing over the row area with similar gypsum rates as for establishment can be used, though lower rates with periodic repeat applications may be more practical.

In soil affected by Mg-rich irrigation water, it is necessary to apply enough gypsum (or other non-alkaline soluble Ca sources) to increase the Ca:Mg ratio >1 and lower the EMP to more acceptable levels (<40%). It is also important to assess the irrigation water quality and apply corrective actions to lower the Mg levels in the water, control the amounts of the Mg-rich water applied to limit or slow Mg build-up and to promote drainage to help leach excess Mg, particularly where gypsum is also used. Like for naturally occurring magnesic soils, gypsum at rates between

2.5 and 10 t/ha can be applied, though this can be applied to the entire field area. During planting, ameliorant incorporation is advised, while top dressing is suitable for ratoon crops.

In both cases, follow-up treatments may be required after several years to counter the loss of Ca and build-up of Mg levels. Periodic testing of the soil is advised to determine the extent to which this is happening and allow refinement to gypsum applications.

Important additional notes on the use of lime and gypsum

- Use of calcitic limes (as a Ca source) in alkaline soils (pH > 7) is of limited value to raise exchangeable Ca levels. Lime is not soluble under high pH conditions and will provide very little soluble calcium to overcome the excess Mg. Soluble sources of Ca are required.
- Very high application rates of gypsum (>10 t/ha) can lead to elevated soluble salt levels (salinity). Where high gypsum rates are required, it is necessary to monitor salt levels and undertake practices to reduce salt accumulation. Drainage and flushing may be required to lower salinity levels.
- In very alkaline soils (pH >8) there is also an increasing risk that applied Ca from gypsum will react to form insoluble Ca-carbonate thus limiting the effectiveness of the gypsum.

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