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Calcareous soils: Problems and their management for enhancing the sugarcane productivity

Vennila, A., Kasthuri Thilagam V. and Palaniswami, C.
Division of Crop Production
ICAR-Sugarcane Breeding Institute, Coimbatore – 641 007
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Introduction

Worldwide, increasing food demand necessitated the adoption of intensive cropping accompanied by technological advancements, while less and less attention was paid to soil health. Soil properties are affected largely by mono-cropping, indiscriminate use of agrochemicals, improper tillage, and water management practices. Pollution and climate change issues further aggravate soil health deterioration.

Soils with a high content of free calcium carbonate ($CaCO_3$) are termed calcareous soils. This excess $CaCO_3$ in the soil affects nutrient availability, plant growth, and soil physical conditions, leading to a reduction in crop yield and quality. In India, nearly 229 m ha (69.4 %) of the land is calcareous. These soils are mostly found in the states of Gujarat, Maharashtra, Bihar, Madya Pradesh, Rajasthan, Uttar Pradesh, and southern states like Andhra Pradesh, Karnataka and Tamil Nadu. In arid and semiarid regions, the low rainfall is insufficient to leach out the soluble weathering products and form calcareousness. The calcareous nature in these soils exists either throughout the profile or within the rooting depth. In waterlogged areas, soluble calcium bicarbonate accumulated during the rainy season is converted into calcium carbonate, causing secondary calcareousness. Although calcareous soils are more common in arid and semiarid regions, they are not restricted to these regions only.

Calcareous soils generally have low organic matter and high soil pH, resulting in less availability of nitrogen, phosphorus, potassium, sulphur and micronutrients, especially zinc, iron and copper, which in turn affects productivity. However, the potential productivity of calcareous soils can be achieved with proper nutrient and water management practices.

Identification of calcareous soil

Calcareous soils can be easily identified visually by their colour and through a simple soil test using an acid. Since calcium carbonate is the major constituent of calcareous soils, the soil may appear pale and whitish. Another effective method is testing with a dilute acid.

For this test, a small amount of dilute hydrochloric acid is applied to the soil; if the soil is calcareous, effervescence (bubbles) will form due to the release of carbon dioxide gas, as shown in Figure 1. Farmers can also use lemon juice instead of hydrochloric acid.

Effervescence in the calcareous soil

Crop Production Challenges in Calcareous Soils

Calcareous soils contain excess amounts of calcium carbonate, which significantly affects soil properties and crop production. Crops grown in these soils face physical constraints and low phytoavailability of nutrients. Soil crust formation is a major physical problem in calcareous soils; it reduces water infiltration, increases runoff, affects seedling emergence during early stages, and results in poor crop stand. The formation of a subsurface hardpan is another constraint, restricting water percolation and root penetration, thereby adversely affecting crop growth and production. Calcareous soils also have low available soil moisture content due to altered soil structure and the presence of a hardpan. Surface crusting, along with hardpan development and low available moisture range, necessitates appropriate management strategies to achieve good yields.

Restricted phytoavailability of nutrients and low organic carbon content further impair soil functions in calcareous soils. The pH of these soils usually ranges between 7.0 and 8.3 and is associated with high buffering capacity. Soils containing $CaCO_3$ along with sodium carbonate may exhibit a pH greater than 8.5. Under wet conditions, dissolution of $CaCO_3$ produces calcium and carbonate ions. These carbonates react with protons to form bicarbonates, resulting in an increase in soil pH. The alkaline soil reaction affects nutrient distribution and phytoavailability through processes such as precipitation or adsorption/occlusion on $CaCO_3$.

Calcareousness imposes multiple stresses on plant nutrition, especially in poorly adapted crops. Plants must cope with elevated calcium and carbonate levels, alkaline conditions that affect ion speciation, reduced nutrient availability, and the formation of insoluble calcium precipitates. These factors lead to nutrient deficiencies, ultimately affecting plant growth and yield. The extent of growth and yield response depends on factors such as soil $CaCO_3$ content, soil texture, plant species, and variety. Sugarcane is particularly poorly adapted to calcareous soils, resulting in alterations in its ionone. Both macro- and micronutrient balances are affected, especially phosphorus, potassium, iron, and zinc.

Nutrient availability and plant uptake

Nitrogen: High pH and $CaCO_3$ affect nitrification and cause volatilization loss of N as ammonia. Low organic matter in these soils also affect the N availability by reduced mineralization.

Phosphorus: Phosphorus is fixed as calcium phosphate or magnesium phosphate in calcareous soils thereby affect the P availability.

Potassium: Calcareous soils have high quantity of available potassium but the antagonism between calcium and potassium ions affect the uptake of potassium. The plants will respond to potassium application in calcareous soils even when the availability of K is high in calcareous soil.

Micronutrients: The availability of zinc, iron, copper and manganese are affected in calcareous soils as the high pH and calcium carbonate content fix these micronutrients as insoluble compounds.

Iron deficiency symptoms

Iron deficiency is most pronounced in sugarcane cultivated in calcareous soils especially in ratoon crop. Iron deficiency in sugarcane is evident clearly as interveinal chlorosis on the younger leaves. The leaves turn complete white in advanced stage. Iron deficiency also restricts the root growth.

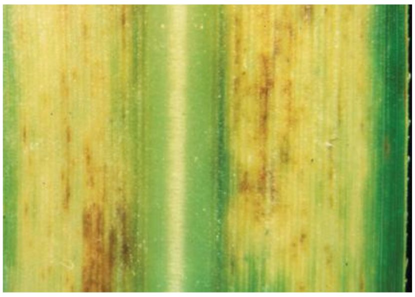


Interveinal chlorosis   Interveinal chlorosis in plant crop Interveinal chlorosis in ratoon crop

Zinc Deficiency symptoms

Zn deficiency is evident on the third and older leaves. Bleached along the veins and green colour stripes on the midrib and the leaf margins. In advanced stage, red lesions may develop between the midrib and the leaf margins.


Stripped effect


Red lesions in leaf

Nutrient requirement of sugarcane

Sugarcane being a long duration crop with C4 metabolism, demands large quantity of moisture, nutrients and sunlight for optimum productivity. An average crop of sugarcane yielding 100 t ha^{-1} of cane removes 208, 53, 280, 30, 3.4, 1.2, 0.6 and 0.2 kg N, P, K, S, Fe, Mn, Zn and Cu, respectively, from the soil.

Management for calcareousness: If the soil pH is less than 8.5, apply 400 kg elemental sulphur per acre in the furrows before planting. For efficient oxidation of elemental sulphur, mix 1 litre *Thiobacillus thiooxidans* with 100 kg FYM and apply in the furrows and irrigate immediately.

- If the soil pH is more than 8.5, broadcast 1000 kg gypsum per acre, impound fresh water, puddle and leach out or apply 400 kg elemental sulphur per acre and 1litre *Thiobacillus thiooxidans* mixed with 100 kg FYM.

Nutrient management for sugarcane in calcareous soil

Nutrient availability in calcareous soils is affected directly or indirectly by the high quantity of free calcium carbonate in the soil. Hence, proper nutrient management is essential. Top dressing of N and K in three equal splits and foliar spraying of micronutrients in this soil enhance nutrient use efficiency and productivity of sugarcane. Calcareous soils have low organic matter to exhibit optimum soil functions for crop production. The addition of organic manures or amendments alleviate the effect of calcareousness and improves soil chemical and physical properties and optimizes soil functioning for crop production.

Nutrient recommendation

Soil testing and application of nutrients based on soil test and crop response, or application of the general blanket dose is recommended.

Basal application

Apply entire dose of SSP and well decomposed FYM @5 t ac^{-1} in the furrows. For ratoon crop, apply 25% excess nitrogen along with SSP and FYM.

Top dressing

Furrow irrigated crop

Top dressing I and II: Apply the recommended dose of N and K in the furrows at 45 and 90 DAP and complete the earthing up and irrigate.

Top dressing III: Apply the recommended dose of N and K in the furrows by pocket manuring at 135 DAP and irrigate.

Drip fertigation

Fertigate with recommended N and K_2O at weekly intervals. Fertigate with 30% of N and K_2O on equal splits from 1^{st} to 12^{th} week for settling transplanting, and from 5^{th} to 12^{th} week for sett planted crops. Fertigate the remaining 70% of N and K_2O on equal splits from 13^{th} to 25^{th} week.

Micronutrient spray

When the symptoms appear spray 1 % of $FeSO_4$ and $ZnSO_4$ micronutrients with Urea (4, 4, and 2 g Urea, $FeSO_4$ and $ZnSO_4$ per litre of water) till 60 DAP and increase the concentration to 1.5% (6, 6 and 3 g Urea, $FeSO_4$ and $ZnSO_4$ per litre water) from 75 to 120

DAP.

Iron Deficiency in Co 11015 After micronutrient foliar spray in Co 11015

Drone spraying of Iron

Drone usage in agriculture is inevitable due to labour shortage and manual spraying in sugarcane is difficult after four months of crop age. Hence, technological advancement in unmanned aerial vehicles has become handy for rescuing farmers by facilitating timely foliar sprays and making the operation easy at any stage of crop growth. Spraying of 2.5% $FeSO_4$ solution @ 25 litre ha^{-1} using drone is recommended to correct the deficiency symptoms during tillering phase. If the deficiency symptom reoccurs, one more spraying using drone may be followed at 30 days interval. Foliar spraying using drone effects timely spraying, reduces wastage of resources and saves 20% cost of foliar spraying.

Conclusion

In calcareous soils, most of nutrients required for crop growth and productivity are frequently limited. Still, the appropriate nutrient management practices can narrow the yield gap between the present productivity obtained by the farmers and maximum attainable yield of sugarcane.