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Sodic Soil: Management strategies

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Abstract

Addressing sodic soil is critical as it significantly diminishes crop yields. Sodic conditions detrimentally impact soil productivity by impeding ventilation, restricting root growth, and promoting root diseases. Elevated levels of exchangeable sodium in soil have adverse effects on plant growth. Consequently, reclaiming and enhancing sodic soil is imperative for bolstering agricultural productivity. Various methods exist for sodic soil reclamation. Firstly, tillage improves sodic soil's physical properties, rendering it more conducive for cultivation. Second method is gypsum application and water leaching to eliminate excess surface salt. Additionallyplant bioremediationor phytoremediation and integration organic matter could be used as better alternative.

Keywords: Sodicity, Gypsum, Organic matter, Exchangeable sodium

Introduction

The widespread presence of sodic soil globally has led to a decline in the value and productivity of most land areas. Sodic soils pose specific challenges and necessitate targeted treatment approaches and management practices for agricultural purposes. Sodic or alkali soil is characterized by an excessive presence of exchangeable sodium, negatively impacting its productivity (Hanay et al., 2004). Structural issues arise when sodium comprises more than 15% of all cations bound to clay particles, leading to the classification of soil as sodic (Davis et al., 2007). The Exchangeable Sodium Percentage (ESP) serves as a crucial indicator of sodicity. In its natural state, when clay particles absorb excess sodium due to their negative charge, the cohesive force between these particles diminishes significantly. Upon saturation, the soil tends to swell excessively due to high sodicity, causing dispersion or decomposition within the soil mass. Upon drying, these clay particles settle, forming dense layers that obstruct pores. This disruption weakens soil aggregation, resulting in structural collapse and pore blockage, limiting water and air movement through sodic soils and thereby impeding crop growth (Qadir and Schubert, 2002). Hence, this article primarily focuses on strategies for sodic soil management.

Effect on soil and plants

- As the level of exchangeable Na rises, it significantly alters the soil's physical characteristics. This results in increased dispersion of the soil, which in turn impacts the germination of seedlings.
- High pH results in nutrient imbalance by reducing availability of many essential nutrients, which reduces crop growth.
- Another factor contributing to suboptimal plant growth in sodic soil is the soil's pH level.
- The predominant harmful elements found in sodic soil comprise Na, Mo, and B. When these ions accumulate to toxic concentrations within plants, they can impede growth, inflict damage, or even lead to plant mortality.

Strategies for management of sodic soil

1. Physical methods

Cultivation enhances soil coverage and infiltration rates, aiding in the leaching of salts from the surface to deeper soil layers, thereby facilitating the reclamation of sodic soils. Various physical techniques for restoring salt-affected soils include deep tillage, periodic water application to flush salt downwards through the soil profile, subsoiling, and similar methods.

2. Chemical methods

The rapid recovery of sodic soil can be accomplished through the introduction of divalent cations via chemical amendments. These cations facilitate the release of soluble calcium sources or the dissolution of calcium ions into the soil, effectively displacing exchangeable sodium. Common materials used for chemical modification include gypsum, lime, $CaCl_2$, sulfuric acid, and sulfur. Gypsum ($CaSO_4$), sourced from both natural and non-natural reservoirs, is the most commonly employed treatment for sodic soil. Its widespread adoption is primarily attributed to its affordability, high solubility, and ready availability. By augmenting the electrical conductivity and cation exchange capacity of sodic soil, gypsum enhances soil permeability.The quantity of gypsum required depends on the concentration of exchangeable sodium present in the specific soil under consideration.Theamount of gypsum required to reclaim the soil is called as “gypsum requirement” (GR) and is calculated as follows:

Gypsum Requirement (GR) = {ESP (initial) - ESP (Final)} *CEC /100

Where ESP (initial) is obtained from the analysis of soil before reclamation orapplication of gypsum, ESP (final) is usually kept at 10, and CEC is the cationexchange capacity in GR or Cmol (p+) kg^{-1} of the soil. Sulfuric acid, typically boasting a purity level of around 95%, is a viscous and corrosive liquid. Upon application to soil containing calcium carbonate, it promptly undergoes a reaction to produce calcium sulfate, consequently yielding indirectly soluble calcium. Similarly, iron sulfate and aluminum sulfate (commonly known as alum) are typically of high purity and readily soluble in water. Upon introduction to the soil and in the presence of water, they dissolve, initiating a hydrolysis reaction. This process leads to the formation of sulfuric acid, which subsequently reacts with the calcium carbonate found in sodic soil, thus providing soluble calcium.

3. Biologicalmethods

In India, gypsum stands out as the primary chemical amendment utilized to expedite the restoration of sodic soil. However, both physical and chemical approaches to sodic soil reclamation are deemed economically inefficient. Consequently, plant bioremediation, or phytoremediation, emerges as a viable alternative to chemical modification, primarily involving the cultivation of salt-tolerant plant species. Integration of organic matter, compost, and plant roots aids in the breakdown of these calcium compounds. Although extensively experimented with, it is widely acknowledged that the selection of an appropriate remediation strategy depends on the geographical location and physico-chemical characteristics of the soil.

Future prospects

Over time, the prevalence of sodium content in affected areas is anticipated to rise due to the utilization of poor-quality irrigated water and ineffective irrigation practices in agriculture. The drawbacks of sodic soil extend beyond physical deterioration to encompass nutritional imbalances, particularly concerning nitrogen and calcium, which contribute to its low productivity. Plant-microbe interaction emerges as a significant bioremediation strategy for sodic soil. Collaboration among researchers from various fields including agronomy, soil science, microbiology, biochemistry, forestry, ecology, analytical chemistry, and genetic engineering is essential for developing comprehensive approaches to examine the functional aspects of chemical-mediated plant-microbe interactions. Through the application of modern research techniques, progress can be made towards the creation of integrated technologies for sodic soil reclamation. This endeavor will pave the way for the enhanced development of beneficial soil bacterial communities, such as methane-oxidizing bacteria, PGPR, cyanobacteria, and salt-tolerant bacteria, among others.

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