Green alchemy: revitalising saline soils through phytoremediation

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Soil salinity and sodicity have become increasingly detrimental environmental factors that significantly affect plant growth. Extensive areas of farmland in semi-arid and arid regions have been impacted by salinity and sodicity. Saline-sodic soils commonly exhibit unfavourable soil physical characteristics, including reduced hydraulic conductivity, infiltration rate, and drainage. Saline and sodic soils have several drawbacks that reduce crop productivity. Despite the various physical, chemical, and biological techniques for reclaiming salt-affected soils, phytoremediation is an innovative approach. Phytoremediation techniques are necessary to improve the physical state of the soil, increase salt leaching, and create more conducive conditions for seed germination. An environmentally acceptable method that may be a viable mitigation strategy for economically rejuvenating salt-affected soil is phytoremediation. Hyperaccumulators can extract salt from the soil in large quantities through a variety of processes, including acidification, phytoaccumulation, phytostabilisation, and phytotransformation. The present review analyses phytoremediation technology as a viable tool for the remediation of salt-affected soils and explores the mechanisms involved. The article describes the mechanisms behind the uptake and translocation of salts in plants, together with the mechanisms used by plants to manage salinity, including avoidance and tolerance systems.

Keywords: Hyper accumulators, phytoremediation, salinity, salt-affected soil, sodicity.

salinity and sodicity damage 6.73 million hectares, or 2.10% of the country's total land area[1–4].

Of the 147 million hectares of degraded soils, 23 million hectares are impacted by salinity, acidity, and alkalinity/sodicity[1]. Every year, 10% of the land is salinised. By 2050, 50% of arable land is expected to be affected by salinity. By 2030, the Indian government intends to restore 26 million hectares of degraded salt-affected soils to expand the land available for agricultural production[1–4]. Over 17 million tons of food grains are produced annually from reclaimed land on 2.18 million acres of salt-affected soils, bringing in an additional Rs 15.5 billion as revenue[1].

Increased concentrations of soluble salts, exchangeable sodium ions, or both are characteristics of salt-affected soils that adversely affect plant growth and development. These salts are mainly composed of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) ion chlorides (Cl^{-}), sulphates (SO_4^{2-}), carbonates (CO_3^{2-}) and bicarbonates (HCO_3^{-}), which together make up most of the ionic composition in such soils. Under arid climatic conditions, the formation of a salt crust on the soil surface often hinders seed germination. This phenomenon is primarily attributed to intense evaporation, which draws soluble salts to the surface, where they precipitate, leading to the development of surface salinity commonly visible as a white crust. Salinity stress reduces turgor pressure in plant cells, adversely affecting their growth[5].

The national institutes, such as the Indian Council of Agricultural Research-Central Soil Salinity Research Institute, and the State Agricultural Universities, are exploring reclamation methods such as gypsum application, sub-surface drainage, the introduction of salt-tolerant crop varieties, and agroforestry. However, the