Biochar as a Soil Amendment for Salt-Affected Soils: Mechanisms, Applications, and the Emerging Potential of Spent Coffee Ground-Derived Biochar

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Abstract:

Salt-affected soils are a group of soils which covers saline, sodic, and saline-sodic types. These represent a significant and growing constraint on global agricultural production, affecting large acreages worldwide. Soil salinity affects plant growth through osmotic stress, ion toxicity, and nutrient imbalance, while sodicity degrades

soil structure through clay dispersion and reduced hydraulic conductivity. Conventional remediation approaches, including chemical amendments such as gypsum and costly leaching regimes, are often economically and logistically prohibitive at scale. Biochar, a carbon-rich pyrogenic material produced through the thermochemical conversion of organic feedstocks under limited oxygen conditions, has received significant academic interest as a low-cost, multifunctional soil amendment with the capacity to ameliorate salt-affected soils through several complementary mechanisms. These include improvements to soil physical structure and water retention, enhanced cation exchange capacity (CEC), shifts in soil pH, and the promotion of microbial activity associated with salt tolerance. The physicochemical properties of biochar such as porosity, surface area, functional groups, and charge characteristics are strongly dependent on feedstock type and pyrolysis temperature, offering potential for tailoring amendment properties to specific soil conditions.

Spent coffee grounds (SCG), a globally abundant organic by-product of the food and beverage industry, represent a promising and underexplored feedstock for biochar production in this context. SCG-derived biochar has a distinctive chemical profile, including nitrogen-rich composition, a well-developed porous structure at intermediate pyrolysis temperatures, and surface functional groups amenable to further modification. While research into SCG biochar for heavy metal immobilisation and organic contaminant remediation is advancing, its application to salt-affected soils remains limited. Preliminary evidence suggests potential benefits through enhanced soil water dynamics and cation buffering capacity, though feedstock-specific effects on sodium adsorption and sodicity indices require systematic investigation. This presentation outlines the mechanistic basis for biochar application in salt-affected soils, critically evaluates an SCG Biochar pyrolysed at 550°C and modified with 30% H_2O_2 its characteristics, and considers the prospective role of SCG-derived biochar as a valorised, circular-economy-aligned amendment for saline and sodic land restoration.

Keywords:

Biochar, Salt affected soils, SCG, Modification.