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Optimizing Soil Health and Remediation Performance in Saline-Sodic Soils via the Combined Effects of Chemical and Organic Treatments

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Abstract

We investigated the individual and combined effects of gypsum, elemental sulfur, vermicompost, biochar and microbial inoculation on soil health improvement in saline-sodium calcareous soils. is degenerating. We have developed linear and non-linear quantitative soil health frameworks to evaluate the effectiveness of remedial measures. Combined organic and chemical treatments; gypsum + vermicompost and elemental sulfur + vermicompost with increases of 134% (0.29 vs 0.68) and 116% (0.29 vs 0.62) in the nonlinear index, significantly increased the effectiveness of the modifications compared with the control. The increase in the overall health index of the soil ranged from 12 to 134%. Microbial inoculation further improves the treatment's impact on soil health. The soil health properties included in the indices explained 29–87% of the variance in wheat growth. The results provide insight into cost-effective and environmentally sustainable methods to rehabilitate degraded saline-sodium soils. In addition, soil health indicators are introduced that provide a quantitative assessment of soil treatment strategies.

Introduction

Future projections of global population growth suggest that restoring degraded lands is essential to meeting the food, feed and fiber needs of approximately 9.8 billion people by 20501. As the world population is growing rapidly, there is an urgent need to improve the state of the global population. land. ecosystem services and agricultural production by restoring degraded land resources (FAO, 2018). Saltwater intrusion and soil calcification are the main soil degradation processes that threaten agricultural production and food security mainly in arid and semi-arid regions of the world. The area of saline soil in the world is estimated to be more than 833 million hectares in more than 100 countries, corresponding to 8.7% of the earth's surface. Soil salinization leads to a loss of 1.5 million hectares of farmland and a loss of productivity by 46 million hectares worldwide each year4. Salt inputs and the dissolution of salt precipitates from irrigation water are the main causes of soil salinity and alkalinity in arid and semi-arid agricultural lands where the supply of nutritious water is unavoidable. added to meet the high evaporation demand [1]. Rapid population growth and climate change could cause the current irrigated land area to expand from about 310 million hectares to 1.8 billion hectares by 2050, exacerbating the problem of salinity5. Saline-sodium soils are recognized as predominant salt-affected soils characterized by both high salinity [electrical conductivity (EC) >4 dS m−1] and acidity [percentage of sodium present in the soil]. exchange rate (ESP) > 15% and sodium adsorption rate (DAS) > 13]. Saline-sodium soils have low yields due to the adverse effects of excessive salt concentrations on the physical, chemical and biological health of the soil and on plant growth [2]. Excessive sodium exchange in saline-sodium soils leads to structural collapse of the soil by dispersing aggregates, solidifying the soil, narrowing the pore size distribution range and thus impeding the acclimatization cycle. mixture of nutrients, water and air. Saline and sodium conditions are known to cause typical biochemical and fertility problems, including deficiencies in nutrients such as P, Fe, Mn, Zn and Cu, as well as toxicity specific ions such as Na+, Cl-, H3BO4- and HCO3-. These conditions also exert osmotic stress on microorganisms and plant cells [3]. The cumulative effects of biochemical and physical stresses can eventually lead to crop failure, economic losses and irreversible soil degradation depending on the salinity and salinity of the surrounding soil. The annual global loss of agricultural production on irrigated land due to soil salinization is estimated at $27.3 billion, even excluding land remediation costs in this estimate.

A significant proportion of saline soils are found in arid and semi-arid regions of West Asia and North Africa. Increasing drought in these areas has led to a greater reliance on irrigation for agriculture. However, excessive salinity has resulted in annual loss of agricultural land. Surface irrigation is the predominant method used in most countries in the region because smallholder farmers, who make up a large portion of the agricultural workforce, cannot afford modern irrigation and treatment technologies. water management. Soil salinity and acidity pose a major agricultural and environmental challenge in Iran, where about 90% of the country is characterized by arid and semi-arid climatic conditions. Recent estimates suggest that 25.5 and 8.5 million hectares of moderately saline and highly saline soils represent nearly 15% and 5.2% of the country's total area, respectively. The adoption of innovative sanitation practices is needed to improve soil health and the productivity of agro-ecosystems in this region [4-6]. Organic modifiers can bind cations and anions and remove them from the soil solution. However, the synergistic effect of many organic modifications or the combination of organic modifications with chemical modifications is largely uncertain.

The primary goal of saline-sodium soil treatment is to reduce salt input through water pretreatment and precise irrigation practices. In addition, a wide range of physical measures, such as tillage, subterranean excavation and drainage, as well as chemical applications, including gypsum, sulfuric acid, basic polyacrylamide, sulfur, Ferrous sulfate, iron disulfide and organic matter, such as manure, poultry manure, compost and biochar have been used to reduce sodium-salt soil. While

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tillage operations are primarily intended to restructure soil particles, chemical treatments focus on replacing exchange salts with calcium or hydrogen ions by adding gypsum or dissolving existing calcium carbonate. using acidic agents such as elemental sulfur or sulfuric acid. In contrast, organic treatment of saline-sodium soils is associated with more comprehensive improvements in the physical, chemical and biological properties of the soil [7-10]. Saline-sodic soils typically have poor structural quality and exhibit a range of limited pore sizes, each supporting different soil functions and services. Thus, limitations on soil aeration, hydraulic conductivity, surface penetration, microbial population and diversity, and root penetration are closely related to the structure of the soil. Poor soil is observed in saline-sodium soils. The organic matter acts as a coagulant for the decomposed soil particles due to the migration of sodium ions into the exchange sites. Besides being directly involved in the retention and exchange of important cations such as Ca2+, K+ and Mg2+, organic additives also facilitate the removal of excess salts from the upper cross-section of the material. soil by improving the flow and diffusion of water [11-14]. Therefore, the different processes observed during the treatment of saline-sodium soils with organic and inorganic agents require an understanding of different organic sources. Although a limited number of investigations attest to the remarkable functional and economic benefits of integrated organic-organic remedial strategies, few studies have explored the potential impact on soil health of these combined methods. In addition, there is a notable absence of comprehensive frameworks for assessing soil health for saline soils to measure the rate of improvement resulting from the revised practice. To the best of our knowledge, the present study constitutes an initial effort to develop a framework for the physical, biological, and chemical assessment of soil health in the context of soil remediation practice. salt-sodium organic-inorganic combination.

Conclusion

Therefore, the objectives of this study were to: (a) develop and evaluate the combined effects of combined treatments on the physical, chemical and biological health of saline-sodium soils, (b) identify key soil characteristics that affect saline-sodium salinity soil health, and (c) develop integrated linear and non-linear indicators of soil health to assess revision overview. The results showed that all the modifications significantly improved the physical, chemical, nutritional and biological health indicators of the soil studied. Combination treatments, especially GP/ES + VC, were found to be most effective in promoting soil health, followed by VC. These results suggest that the presence of VC can significantly increase the impact of GP and ES on improving the health of saline-sodium soils. The numerical value of SHI increased from 12% to 134% after incorporating the modifications into the control soil, depending on the treatment and modeling method. This demonstrates the positive synergistic effect of multiple modifications on SHI, especially those produced by the non-linear model. While the linear and non-linear SHI models showed significant improvements in soil health across all treatments, those with microbial inoculation resulted in higher SHI values. SHI was found to be significantly associated with wheat growth indices, including dry and wet weight, root length and volume. However, the non-linear SHI model more accurately predicts wheat yield and growth parameters than the linear SHI model. Overall, the results suggest that organic supplements such as vermicompost have significant potential to improve the health of degraded saline-sodium soils. Organic amendments can also increase the effectiveness of conventional chemical treatments such as gypsum or elemental sulfur in minimizing the adverse effects of soil salinity and salinity on growth. of crops and agricultural productivity. With the increasing reliance of intensive agricultural systems on chemical inputs, there is a need to develop cost-effective and environmentally sustainable practices. Organic amendments increase the immediate availability of essential nutrients and improve soil resilience to internal and external stresses by reorganizing soil structure.

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