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Effect of organic amendments and microbial application on sodic soil properties and growth of an aromatic crop

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ABSTRACT

In this experiment, we studied the effects of microbial inoculation, vermicompost and sludge application on physical, chemical and microbial properties of sodic soil and growth of *Ocimum basilicum* (holy basil). Sodic soil collected from natural field was amended with two bacterial strains A and C (isolated from the same soil), vermicompost and tannery sludge @ 5 t ha^{-1} upto 0–15 cm soil depth of field buried cement barrels (125 cm height, 49.5 cm diameter) in such a way that nine treatments (control sodic soil (T_0), vermicompost or VC (T_1), VC + strain A (T_2), VC + strain C (T_3), VC + strain A and C (T_4), tannery sludge or TS (T_5), TS + strain A (T_6), TS + strain C (T_7), and TS + strain A and C (T_8) were formed. After application of these treatments, soil was incubated for one month at constant moisture. After one month of incubation period, 35 days old seedlings of *O. basilicum* were planted in barrels. Significant changes in soil properties (physico-chemical, microbial and enzyme activities), due to application of microbes and organic amendments, were observed after one month of incubation (AIS) and at crop harvest (ACH). On an average soil pH, electrical conductivity (EC), exchangeable sodium (Na), soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN), soil respiration (SR), microbial quotient (C_{mic}:C_{org}), and metabolic quotient (qCO_2) were significantly higher in incubated soils than crop harvested soils. Study concludes that use of vermicompost, sludge and microbial inoculants increase soil fertility and enhance yield and oil quality of *Ocimum basilicum*. Furthermore, incubation for one month before crop plantation was sufficient time for amendments to facilitate changes in sodic soil properties.

1. Introduction

Soil degradation resulting from salinity and sodicity is a major environmental constraint with severe negative effects on soil fertility and agricultural productivity in arid and semiarid regions of the world (Lambers, 2003; Young et al., 2015). Sodic soils suffer from high level of pH (>8.5), exchangeable sodium percentage (ESP) >15, sodium adsorption ratio (SAR) >15 (US Salinity Laboratory Staff, 1954) and low fertility (Wong et al., 2010). An excess amount of exchangeable sodium in sodic soil reverses the process of aggregation and causes soil aggregates to disperse into their constituent individual soil particles (Sumner, 1993) and makes soil physically unfit (Nelson et al., 1998; Fig. 1). The structural imbalance of soil particle causes damage to microbial cells, their activities and in turn nutrient availability (Singh, 2015). An important step toward the reclamation of sodic soils is the identification of suitable amendments tools. For this purpose, physical method (Choudhury et al., 2014; Ganjegunte et al., 2014; Singh et al., 2016a) and chemical (gypsum) (Sadiq et al., 2007; Sahin et al., 2011), organic (farm yard manure, crop residues, leaf litters and industrial effluents) (Tejada et al., 2006; Dendooven et al., 2010; Singh et al., 2016b; Oo et al., 2015) and biological (afforestation, Plant Growth Promoting Rhizobacteria and Mycorrhyza) (García and Mendoza, 2007; Singh et al., 2013a; Wu et al., 2014; Singh et al., 2015) amendments have been used. In recent studies attention has been turned to study the impact of these amendments on soil microbial activities (Tejada et al., 2006; Yuan et al., 2007) and use of microbes or microbial consortia (Sahin et al., 2011; Paikray and Singh, 2011; Ashraf et al., 2013) for reclamation of salt-affected soils. Understanding the changes in soil fertility, crop productivity and microbial activities due to use of microbial consortia along with industrial wastes can provide an empirical solution for sodic soils.

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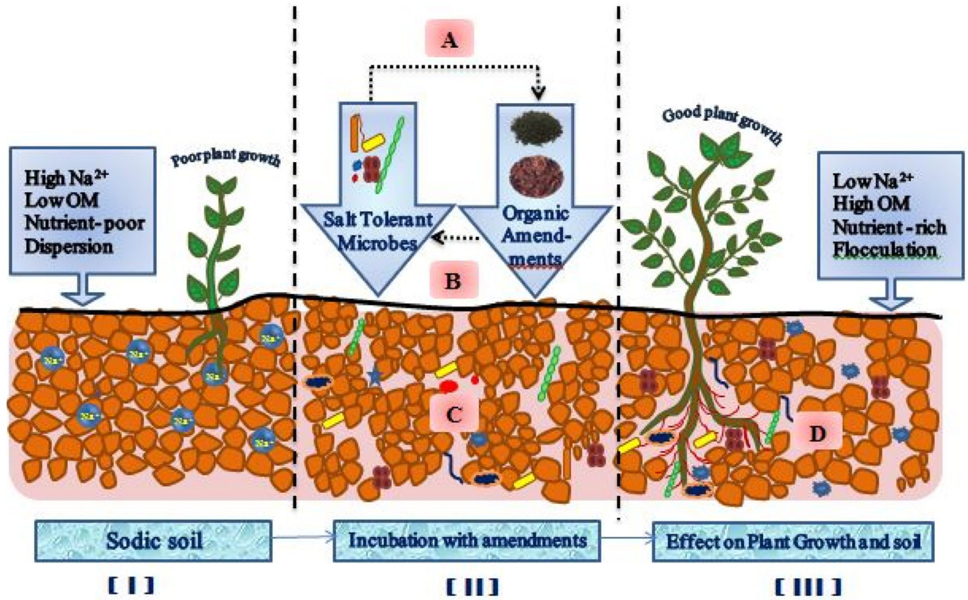

Fig. 1. Conceptual diagram showing various conditions of sodic soil. (I) Sodic soil in field conditions is generally very compact and hard with dispersed clay minerals due to access of Na^{2+} in their cation exchange complex, low organic matter (OM) and poor water moment. (II) Application of bacterial strains, isolated from sodic soils, in various combination with vermicompost and sludge increase soil aggregation, microbial population (of applied as well as inherent microbes) and nutrient status during incubation period; (A) acceleration of decomposition rate of organic amendments through biochemical activities of microbes, (B) increase in growth and metabolic activities of microbes using organic amendments as substrates, (C) formation of macroaggregates. (III) Improved soil structure and increased soil fertility affect aboveground and belowground plant growth; (D) reclaimed sodic soil with stabilized rhizospheric microbial community and improved soil structure and plant growth.

Soil microbes are effective in increasing plant growth and maintaining soil health by releasing important plant nutrients through solubilization, release of plant growth hormones and mineralization of inorganic and organic pools of soil (Fig. 1). Soil salinity and sodicity have adverse effects on growth and activities of soil microbes (Rietz and Haynes, 2003). Therefore, use of salt tolerant microbes can maintain nutrient cycling in saline-sodic soils through production of functional enzymes like β-glucosidase, phosphatase, protease, amylases, urease etc., and compatible solutes and other metabolites (Dendooven et al., 2010). Further, this is likely to enhance activity microbes in the soil those are not salt tolerant.

Although, use of salt-tolerant microbes in ameliorating saline and sodic soils is a common practice, the identification of potential mechanisms underlying this process in field studies is challenging. Understanding the alterations in soil microbial activities in relation to changes in soil sodicity (Yan and Marschner, 2013) and effects of microbial inoculation on soil properties is important (Sahin et al., 2011). Earlier studies support the hypothesis that sodicity affects physico-chemical (Dendooven et al., 2010), microbial (Setia et al., 2011a,b; Yan & Marschner, 2012) and enzyme activities (Rietz and Haynes, 2003; Tripathi et al., 2007; Singh et al., 2012; Singh, 2015) of soil. Lower values of enzyme activities in saline soils than in non-saline soils might be due to 'salting-out' effect which involves a decrease in enzyme solubility through dehydration, thus altering the enzyme 'catalytic site'; enzymes in saline soils are less protected and perhaps they were denatured by proteolysis (Garcia et al., 2000).

The effectiveness of various amendments in reclamation of sodic soils and their effects on microbial activities of saline and sodic soils has been studied with diverse results. The addition of organic wastes had a positive effect on the activities of soil enzymes (Tejada et al., 2006). Yan and Marschner (2013) reported increased activity and growth of soil microbial community along with decrease in the salt concentration and increase in added organic substrate. López-Valdez et al. (2010) reported increase in CO_2 emission after addition of sewage sludge to extreme alkaline (sodic) soil. The fungal isolates (*Aspergillus* spp.; FS 8, 9 and 11) and two bacterial strains (*Bacillus subtilis* OSU 142 and *B. megaterium* M3) along with gypsum were used to increase saturated hydraulic conductivities of four different saline–sodic soils (Sahin et al., 2011). Authors reported that microorganisms tested in the present study have potential to improve water movement through saline–sodic soils. But little is known about carbon-nitrogen dynamics and response of microbial and enzyme activities after application of salt tolerant microbes along with different organic amendments to sodic soils. Therefore, in this study an attempt has been made to fill this research gap with following objectives: (i) to isolate salt-tolerant microbes from sodic soils, (ii) to use isolated microbes along with vermicompost (VC) and sludge (TS) for reclamation of sodic soil, (iii) to know effect of these amendments on soil properties after one month field incubation/before crop plantation and (iv) to assess changes in soil properties after crop harvest and determine crop yield including oil quality. We hypothesized that (i) isolated microbes used in various combinations with organic amendments shall have diverse effects on soil properties and (ii) there will be significant effect of field incubation on soil properties that may or may not be significant after crop harvest.

2. Materials and methods

2.1. Sodic soil, sludge and vermicompost

Abandoned sodic lands are widely spread in rural areas of Lucknow district of Uttar Pradesh (Shukla et al., 2011; Singh et al., 2013b). For the current study, we collected sodic soils from Ranipur village (Singh et al., 2013b). Geographically this region belongs to the middle part of the Gangetic alluvial plain in north India, where sodic soils are found interspersed with crop fields to a considerable extent (Singh et al., 2013b). The soil is classified as sandy loam soil, with 6% clay, 40% silt and 54% sand (Bouyoucos, 1962). Soil was processed (removal of concrete and plant debris, mixing and homogenization) and sieved through a 2 mm screen for physical, chemical and microbial analysis. Microbial (isolation of bacterial stains, microbial biomass and respiration) and biochem-