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Influence of salinity and water content on soil microorganisms

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Abstract

Salinization is one of the most serious land degradation problems facing world. Salinity results in poor plant growth and low soil microbial activity due to osmotic stress and toxic ions. Soil microorganisms play a pivotal role in soils through mineralization of organic matter into plant available nutrients. Therefore it is important to maintain high microbial activity in soils. Salinity tolerant soil microbes counteract osmotic stress by synthesizing osmolytes which allows them to maintain their cell turgor and metabolism. Osmotic potential is a function of the salt concentration in the soil solution and therefore affected by both salinity (measured as electrical conductivity at a certain water content) and soil water content. Soil salinity and water content vary in time and space. Understanding the effect of changes in salinity and water content on soil microorganisms is important for crop production, sustainable land use and rehabilitation of saline soils. In this review, the effects of soil salinity and water content on microbes are discussed to guide future research into management of saline soils.

Keywords: Salinity; Water content; Soil microorganism

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1. Introduction

It is predicted that the human population will reach 8 billion in 2025. To avoid or minimize food shortage, saline soils have to be rehabilitated and managed to meet the food demand of an ever growing human population (Ladeiro, 2012). Soil microorganisms constitute less than 0.5% (w/w) of the soil mass, but they play a key role in soil properties and processes. Salinity affects plants and microbes via two primary mechanisms: osmotic effect and specific ion effects (Oren, 1999; Chhabra, 1996). Another factor influencing plants and microbes is soil water content. Soil water potential which relates to the energy level by which the water is held in the soil also closely related to soil salinity, it is influenced by osmotic potential in the soil solution.

2. The importance of soil microorganisms for nutrient cycling

Soil microorganisms constitute less than 0.5% (w/w) of the soil mass, but they play a key role in soil properties and processes. Soil microbes include bacteria, archaea, fungi, protozoa and viruses (Tate, 2000). Microorganisms participate in oxidation, nitrification, ammonification, nitrogen fixation, and other processes which lead to decomposition of soil organic matter and transformation of nutrients (Amato & Ladd, 1994), they can also store C and nutrients in their biomass which are mineralized after cell death by surviving microbes (Anderson & Domsch, 1980). Our understanding of these processes increased considerably in recent years with advances in molecular and analytical methodologies which have led to more successful strategies to modify them for a range of ecosystem services (Frey, Six, & Elliott, 2003; Gessner et al., 2010; Rillig & Mummey, 2006).

Nutrient cycling is the flux of nutrients within and between the various biotic or abiotic pools in which nutrients occur in the soil environment (Brady & Weil, 2002). Microorganisms have a major impact on the cycling of elements, most of which are essential for the growth of living organisms. Bacteria, archaea and fungi, in particular, are crucial for the cycling of several important inorganic nutrients in soils. Through oxidation, ammonification, nitrogen fixation and other processes, organic materials are decomposed, releasing essential inorganic plant nutrients to the soil. Nitrate (through nitrification), sulfate (through sulfur oxidation), phosphate (through phosphorus mineralization) are present in soils primarily due to the action of microorganisms. Therefore, microbes are essential to maintain a productive and valuable soil system. Disturbance of the soil environment, such as land use change or soil cultivation, can shift microbial communities and can have detrimental effects on soil nutrient cycling (French et al., 2009).

In addition, the emission of CO_2 from soils, which includes respiration from soil organisms and roots, contributes approximately 10% to atmospheric CO_2 (Raich & Potter, 1995). Microbes also play an essential role in the formation of humic substances which are stable forms of organic C and critical for organic C sequestration in soils (Burns et al., 1986). (Fig. 1).

3. Soil salinity

3.1. Soil salinity definition

A soil that contains excess salts so as to impair its productivity is called a salt-affected soil. Salt in the soil can influence soil processes through the salt concentration in the soil solution (salinity) which determines the osmotic potential and the concentration of sodium on the exchange complex of the soil (sodicity) which influences soil structural stability. Salinity can, over time, lead to sodicity. The major soluble salts in soils are the cations Na^+ (sodium), Ca^{2+} (calcium), Mg^{2+} (magnesium) and K^+ (potassium), and the anions Cl^- (chloride), SO_4^{2-} (sulfate), HCO_3^- (bicarbonate), CO_3^{2-} (carbonate) and NO_3^- (nitrate) (Shi & Wang, 2005). There are several classification systems for salt-affected soils in the world, for example the USDA system, the USSR system and the Australian