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Rhizosphere-induced weathering of minerals in loess-derived soils of Golestan Province, Iran

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ABSTRACT

Weathering of minerals is the major source of nutrients to plants. The rhizosphere can play a central role in the weathering of minerals through the release of acid exudates that drive hydrolysis of minerals. Although many studies have examined the weathering of pure natural industrial minerals in rhizosphere, information on the weathering of clay and silt minerals from soils is limited. This study examined the weathering and K release of minerals in clay and silt fraction in the rhizosphere of corn. Growth medium was a mixture of quartz sand as filling materials and clay and silt fraction of four dominant soils formed on loess parent material with different characteristics (i.e., Aridisols, Alfisols, Inceptisols and Mollisols). During 100 days of the experiment, plants were irrigated with distilled water and complete and K-free nutrient solution as needed. At the end of cultivation, plants were harvested and their K uptake was measured. Clay and silt fractions were separated from quartz sand and analyzed by X-ray diffraction (XRD) and XRF both before and after the experiment. Intense weathering of mica and chlorite was observed in silt fraction of Aridisols and Mollisols. The high acidity of the rhizosphere induced by root exudates has resulted in the release of structural K from mineral lattice. In contrast to the silt fraction, the X-ray patterns of the clay fraction showed minor changes following plant growth such as the formation of mixed layer mica-vermiculite and vermiculite. The K content extracted by corn was significantly greater for silt than the clay sizes. The highly weatherable silt sized minerals therefore, could be regarded as the major source of nutrients to plants.

1. Introduction

Potassium is one of the most essential macronutrients for plants because it plays a central role in several physiological processes in plant nutrition (Al-Zubaidi et al., 2008; Marschner, 2008). Potassium in soil is often divided into exchangeable, non-exchangeable, soluble and structural forms (Sparks, 1987). Between 90 and 98% of total soil potassium is in structural forms and the remaining 2–10% is found either as non-exchangeable or exchangeable and soluble forms (Brady and Weil, 2007). The most important source of potassium in soil is K-bearing minerals including alkali feldspar, muscovite, biotite and illite, which release K by weathering (Marschner, 1995; Mengel, 2007). In fact, if the amount of soluble and exchangeable K reach low levels due to K uptake by plants (Mclean and Watson, 1985), non-exchangeable K from the interlayer of K-bearing minerals is released into the soil solution (Tributh et al., 1987). Barré et al. (2007) demonstrated that interlayer K of K-bearing clay minerals chemically known as non-exchangeable is available for plants. Velde and Peck (2002) reported the clay mineral transformation induced by K depletion. Barré et al. (2008a) showed that 2:1 clay minerals behave as a huge and a renewable K reservoir.

Until now, few studies have investigated the role of plant roots and associated microorganisms in the rhizosphere zone on the transformation and dissolution of clay minerals. The rhizosphere, defined as the volume of soil that is directly influenced by root secretion and associated soil microorganisms, differs in many aspects from the bulk soil as a result of water and nutrient uptake by roots and to root respiration and microbial activity. The chemical changes that occur in the rhizosphere was demonstrated by some authors (e.g., Bakhshandeh et al., 2011; Norouzi and Khademi, 2010; Shelobolina et al., 2012). Root activity in the rhizospheric zone can influence the soil weathering processes by decreasing pH, production of mucilaginous material and excreting organic acids (Drever, 1994; Kodama et al., 1994). Some associated soil microorganisms are able to dissolve K-bearing minerals by excreting organic acids, which directly solubilize K-bearing minerals or chelate silicon ions to release K into soil solution (Basak and Biswas, 2009).

In the last few years, several studies were carried out on mineral weathering with pure minerals (Hinsinger and Jaillard, 1993; Hinsinger et al., 1992) comparing the rhizosphere soil with non-

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