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Microbial biomass and activity in alkalized magnesic soils under arid conditions

Bing-Cheng Yuan[a,b], Xue-Gong Xu[c], Zi-Zhen Li[b,d,*], Tian-Peng Gao[e], Meng Gao[d], Xian-Wei Fan[b], Jian-Ming Deng[b]

[a]*School of Real Estate, Beijing Normal University Zhuhai Campus, Zhuhai 519085, China*
[b]*Key Laboratory of Arid Agroecology under the Ministry of Education, Lanzhou University, Lanzhou 730000, China*
[c]*College of Urban and Environmental Sciences, Peking University, Beijing 100871, China*
[d]*School of Mathematics and Statistics, Lanzhou University, Lanzhou 730000, China*
[e]*Chemistry Department, Lanzhou City University, Lanzhou 730070, China*

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Abstract

The effects of salinity and Mg^{2+} alkalinity on the size and activity of the soil microbial communities were investigated. The study was conducted along the border area of the alluvial fan of the Taolai River. Thirty soil samples were taken which had an electrical conductivity (EC) gradient of 0.93–29.60 mS cm^{-1}. Soil pH ranged from 8.60 to 9.33 and correlated positively with Mg^{2+}/Ca^{2+} ratio, exchangeable Mg^{2+} percentage and $HCO_3^- + CO_3^{2-}$. Mg^{2+}/Ca^{2+} varied considerably from 3.04 to 61.31, with an average of 23.03. Exchangeable Mg^{2+} percentage generally exceeded 60% and had a positive correlation with Mg^{2+}/Ca^{2+}. $HCO_3^- + CO_3^{2-}$ averaged 1.63 cmol kg^{-1} and usually did not exceed 2.0 cmol kg^{-1}.

Microbial biomass, indices of microbial activity and the activities of the hydrolases negatively correlated with Mg^{2+}/Ca^{2+} or exchangeable Mg^{2+} percentage. Biomass C, biomass N, microbial quotient (the percentage of soil organic C present as biomass C), biomass N as a percentage of total N, potentially mineralizable N, FDA hydrolysis rate and arginine ammonification rate decreased exponentially with increasing EC. The biomass C/N tended to be lower in soils with higher salinity and Mg^{2+} alkalinity, probably reflecting the bacterial dominance in microbial biomass in alkalized magnesic soils. The metabolic quotient (qCO_2) positively correlated with salinity and Mg^{2+} alkalinity, and showed a quadratic relationship with EC, indicating that increasing salinity and Mg^{2+} alkalinity resulted in a progressively smaller, more stressed microbial communities which was less metabolically efficient. Consequently, our data suggest that salinity and Mg^{2+} alkalinity are stressful environments for soil microorganisms.

Keywords: Salinity; Magnesium alkalinity; Microbial biomass; Microbial activity; Metabolic quotient; Hydrolase activity

1. Introduction

Soil salinity is an escalating problem worldwide. Naturally occurring salt-affected soils cover about 1 billion hectares, which represent about 10% of the earth's continental surface, and up to 100 Mha have been salinized due to irrigation (Ghassemi et al., 1995; Pessarakli and Szabolics, 1999). In China salt-affected soils are estimated to be about 99 Mha (Wang et al., 1993). Salt-affected soils occur for the most part in arid or semiarid regions, where evaporation greatly exceeds precipitation and salts dissolved in the ground water reach and accumulate at the soil surface through capillary movement. Salt-affected soils are practically non-existent in humid regions, except when the soil has been subjected to sea water in river deltas and other low-lying lands near the sea. Salt-affected soils are traditionally divided into three broad categories depending on the extent to which they are saline or sodic (Richards, 1954). These categories are based upon

*Corresponding author. Key Laboratory of Arid Agroecology under the Ministry of Education, Lanzhou University, Lanzhou 730000, China. Tel.: +86 931 4565095; fax: +86 931 8912823.
E-mail address: zizhenli@126.com (Z.-Z. Li).

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the electrical conductivity (EC) of the saturation paste extract, exchangeable Na^+ percentage, and pH (Richards, 1954).

In spite of the large volume of work on saline and sodic soils, soils with high Mg^{2+} alkalinity have not received the same attention. In China, alkalized magnesic soils are principally sporadically distributed along the border areas of the alluvial fans of the Taolai River in the Jiuquan Basin and the Shule River in the Anxi Dunhuang Basin of the Hexi Corridor in Gansu Province, the Kaidu River in the Yanqi Basin in Xinjiang Autonomous Region (Wang et al., 1993). In these areas, alkalized magnesic surface soils formed, as is evident from high soil pH and exchangeable Mg^{2+} percentage. Mg^{2+} alkalinity exerts unfavourable effect on vegetal productivity of soils directly or through unsatisfactory physical soil environment. Our present knowledge on Mg^{2+} alkalinity is far from being complete.

Salinity and sodicity have a range of adverse effects on the physical and chemical properties of soil, microbiological processes and plant growth. While the effects of salinity and sodicity on soil chemical and physical properties and plant growth are well documented, their effects on soil microbial processes remain relatively unstudied. Some investigations have been undertaken in naturally saline soils (Zahran et al., 1992; Sarig and Steinberger, 1994; Sarig et al., 1996; Batra and Manna, 1997; Zahran, 1997; Rietz and Haynes, 2003; Sardinha et al., 2003; Mamilov et al., 2004), and the depressive influence that salinity and sodicity inflict on soil microbial communities and their activities has been reported in most studies, but little is known regarding the effects of Mg^{2+} alkalinity. Where salinity has been induced, both increases and decreases in mineralization of C and N with increasing salinity have been observed (Laura, 1974; McClung and Frankenberger, 1987; Nelson et al., 1996; Pathak and Rao, 1998). It has been reported that salinity and sodicity inhibited the enzymes activities (Frankenberger and Bingham, 1982; Pathak and Rao, 1998; Rietz and Haynes, 2003), but the effects of Mg^{2+} alkalinity remain, as yet, unreported. Since soil organic matter input and consequently microbial biomass and activity are typically concentrated in the top few centimeters of the soil (Lavahun et al., 1996; Murphy et al., 1998), Mg^{2+} alkalinity near the surface of soil may greatly affect a series of microbially mediated processes. This is a great concern in that microbial processes in soils control ecological function and soil fertility.

The general objectives of the present study were to investigate: (1) the chemical properties of alkalized magnesic soils at Bianwan in the Jiuquan Basin, Gansu Province, China; (2) how gradients in salinity and Mg^{2+} alkalinity had affected soil microbial biomass, basal respiration, FDA hydrolysis rate, arginine ammonification rate, potentially mineralizable N and hydrolases activity; and (3) the relative effects that salinity and Mg^{2+} alkalinity had on soil microbial properties and related processes.

2. Materials and methods

2.1. Study site

The study was conducted in Bianwan (39°58′–40°03′N latitude, 98°30′–98°39′E longitude), situated along the border area of the alluvial fan of the Taolai River, a tributary to the Hei River, one of the two largest inland rivers in China. The Taolai River originated from the Qilian Mountains, and melt water from glaciers and snow cover is the principal source of surface runoff. The river flows towards and then disappears in the piedmont plain. The ground water table is at a depth of 1.5–2.0 m, with periodic rise during the year. The native grassland community, with a basal cover of 25–30% of the soil, is comprised of over 10 species of grasses and shrubs, but dominated by three stunted grass species: *Agropyron cristatum* (*L.*) *beauv., Phragmites communis Trin. and Achnatherum splendens* (*Trin.*) *Nevski.* The climate of the area is medium temperate arid, with an annual mean air temperature of 7.3 °C, annual mean precipitation of 85.3 mm, and an average annual pan evaporation of 2148.8 mm. The ratio of pan evaporation to rainfall for the area is 25.2. The average maximum and minimum temperatures are 21.8 °C (July) and −9.7 °C (January), respectively.

2.2. Soil sampling and analysis

Ten sites, 1.6–1.9 km apart from each other, with different salinity and Mg^{2+} alkalinity levels were selected in the study along the border area of the alluvial fan of the Taolai River. The sites offered a wide range of plant cover density, from practically bare soils to grassland soils with a high percentage of plant cover. Three independent samples within an area of 50 m radius, each consisting of five soil cores (2 cm diameter × 20 cm), were taken from the top soil of each study site in August 2005. After carefully removing the surface organic materials and fine roots, each composited moist field soil sample was mixed, homogenized and sieved through a 2 mm mesh screen. Microbial and biochemical analyses were carried out on field moist subsamples, and physicochemical analyses were performed on air-dried subsamples.

Organic C was analysed by dichromate oxidation method. Total N was estimated by Kjeldahl method. Microbial biomass C and biomass N were estimated by the chloroform fumigation extraction method (Brookes et al., 1985; Vance et al., 1987). Microbial biomass C was calculated as follows: Microbial biomass $C = E_C/k_{EC}$, where E_C = (organic C extracted from fumigated soils)–(organic C extracted from non fumigated soils) and $k_{EC} = 0.38$ (Vance et al., 1987; Joergensen, 1995). Microbial biomass N was calculated as follows: Microbial biomass $N = E_N/k_{EN}$, where E_N = (total N extracted from fumigated soils)–(total N extracted from non fumigated soils) and $k_{EN} = 0.54$ (Brookes et al., 1985). Basal