



Application forms and types of soil acidity corrective: Changes in depth chemical attributes in long term period experiment



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ABSTRACT

The main interest of the soils acidity correction is to neutralize the exchangeable Al^{3+} , since the presence of this form of Al in the soil restricts root growth and, consequently, decreases the productivity of sensitive crops. Thus, monitoring the advance of the attributes related to soil acidity in depth in the cultivated areas is fundamental to understand the dynamics of the correction on the surface, helping in the decision-making on the reapplication of the limestones. The aim of this study was to quantify the chemical changes in the soil caused by lime application with different Ca:Mg ratios 141 months after its application. The experiment was installed in 2004 under native field in a Typic Hapludalf. The statistical design was a two-factor type with two types of application forms (incorporated and superficial) and five types of limes (a control and lime with Ca:Mg molar ratios of 35.5 (calcitic), 9.0, 5.0, and 3.2 (dolomitic). In July 2016, 36 trenches were opened in each plot and soil samples were collected at depths of 0–60 cm. In the soil layer of 0–10 cm, the soil samples were collected every 1 cm. In the layer of 10–25 cm, the soil samples were collected every 2.5 cm, and in the layer of 25–60 cm, the samples were collected every 5 cm. In total, 25 depths per trench were sampled, totaling 828 soil samples used for the chemical analyses. The analysis performed were: values of pH in water in the ratio 1:1, Santa Maria Buffer (TSM) an adaptation of SMP (Schoemaker et al., 1961), Ca, Mg, and Al exchangeable. The saturation by Al and bases was calculated. Twelve years after the application, the simple deposition of the dolomitic lime on the surface of the soil allowed changes in the attributes related to soil acidity in the profile, changes that were like the incorporation. The use of the calcitic lime provided more significant alterations in the attributes related to soil acidity in the profile compared to the dolomite, given its greater solubility in relation to dolomite. Almost twelve years after the natural acidity correction of the soil following the recommendations of the Soil Chemistry and Fertility Commission -RS / SC (2016), a slight reacidification of the soil of the 0–5 cm layer was observed, whose aluminum saturation is still less than 5% in the first 10 cm. Even almost twelve years after the corrective application, superficial or incorporated, still significant migration of the alkalinizing front in the soil profile to depths greater than 20 cm is seen.

1. Introduction

The process of rock weathering promotes the release of various chemical elements, which can be beneficial or harmful to the development of plants. Its reactive aluminum form (Al^{3+}) can remain connected to the surfaces of negatively charged particles (Eimil-Fraga et al., 2015), can form aluminum-organo complexes in soil organic matter, and re-precipitated in the form of iron oxides. Iron oxides are common in natural environments and typically contain large amounts

of impurities. It is a result of coprecipitation/re-precipitated processes. Coprecipitation of Al with Fe oxides occurs, for example, during alternating reduction-oxidation cycles that promote dissolution of Fe from Fe-containing phases and its re-precipitation as Fe–Al oxides (Bazilevskaya et al., 2011). And also drained for the inter-layers of 2: 1 clay minerals (Bertolazi et al., 2017). Due to the great toxic potential of Al^{3+} for plants (Singh et al., 2017), soil pH correction is a global agricultural practice. The main problem is the restriction of root growth and, consequently, the decrease in the productivity of sensitive crops. In

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the 1960s, significant production damage caused by high soil acidity and the presence of Al^{3+} resulted in the creation of the first governmental and cooperative soil acidity correction program in Rio Grande do Sul in the south of Brazil (Mielniczuk, 1999).

For the soil, acidity correction farmers use metamorphic rocks (marble) or lime rocks (limestone), generally called soil acidity correctives, which consist of carbonates, mainly calcite, but may also contain dolomite. In these rocks, when the ions of Ca are replaced by Mg, the crystalline structure changes, decreasing its solubility. As a result, correctives containing smaller crystals of calcite induce greater solubility to the corrective compared to pure Mg carbonate (Grunwaldt et al., 2016; Li et al., 2013; Morse and Arvidson, 2002).

The anions resulting from the dissociation of the soil acidity correctors (HCO_3^- and OH^-) react with the protons of the soil solution resulting in the neutralization of Al^{3+} . Because of this reaction, desorption of the weakly adsorbed Al^{3+} and even the hydrogen of the functional groups occurs. So, these reactions are limited to the soil in contact with corrective particles, since their solution is controlled by their dissociation and depends on the presence of protons in the soil solution (Kaminski et al., 2005; Weirich Neto et al., 2000).

When the site of the dissolution/dissociation is far from acidity zone, the neutralization of: (i) active acidity, (ii) adsorbed Al^{3+} and (iii) the hydrogen contained on soil functional groups, is very limited, especially when the lime is deposited on soil surface. Despite of low solubility, some particles of limestone move along the soil profile, reaching greater depths. Many studies have observed changes in the soil acidity attributes on subsurface layers (up to 60 cm depth) when the lime was applied only on the soil surface (Castro and Crusciol, 2013; Crusciol et al., 2016; Gatiboni et al., 2003; Joris et al., 2016; Kaminski et al., 2005; Rheinheimer et al., 1998, 2000).

Two mechanisms are identified as responsible for the formation of an alkaline correction front. The first one is the movement of corrective particles in depths "accidentally" resulting from the turbulent downward movement of water via macropores (Amaral et al., 2004). In natural systems, as there is no anthropic interference, biopores and the structure of good soil quality allow the formation of channels, which are kept intact and continuous in the soil profile (Gassen and Kochhann, 1997; Molope et al., 1987). The non-mobilization of the soil and the accumulation and stabilization of organic matter determine an environment conducive to the activity of worms, insect larvae and other organisms as well as to the increase of microbial activity (Amaral et al., 2004). These processes contribute to the formation and stabilization of soil aggregates, improving their structure (Molope et al., 1987) and favoring water infiltration.

When these physical properties are preserved, instantaneous infiltration rates in no-tillage and native pasture systems are high (da Silva and Delatorre, 2009), due to the equilibrium reached in the ecosystem. The presence of straw on the soil surface and the absence of soil rotation results in improvements in physical and biological characteristics (Souza et al., 2013). These improvements favor the descent of the limestone by preferential channels formed by the increase of porosity, canaliculi formed by the dead roots and biopores formed by the meso and macrofauna of the soil.

The second mechanism that may explain the changes in the soil acidity attributes of subsurface layers when deposited at soil surface is the adsorption/desorption of cations by organic anions soluble in the soil solution, including those formed from the dissociation of limestone (HCO_3^- and OH^-) (Miyazawa et al., 2002). This mechanism does not involve acid-base reactions; it is simply based on the formation and migration of soluble organic salts in the soil profile. Organic acids with a low number of carbon atoms can be excreted by the root system or produced by microbiological decomposition of plant residues, part of which remains in the soil solution or in the soil solution interface zone (Kleber et al., 2007). Therefore, due to the high concentration of Ca and Mg (by-products of the dissociation of the correctives), there will be the formation of soluble complexes. This phenomenon (of complex

formation) does not affect the alteration of soil acidity attributes. The mechanism is related to the migration of this complex in the soil profile through water movement. As the descent occurs in the profile, the exchange of Al by Ca or Mg occurs, since the solution of the soil in subsurface is poorer in Ca and Mg, and richer in Al. Some published works have demonstrated that this mechanism increases the mobility of Ca and decreases the Al^{3+} activity of the soil solution of the subsurface layers when applying the corrective surface and adding vegetal residues (equivalent to 40 Mg ha^{-1} dry mass) (Cassiolato et al., 2000; Franchini et al., 2001; Miyazawa et al., 2002).

Regardless of the mechanism of migration of the effects of the addition of limestones, two factors are paramount for the magnitude of the mechanisms: time and water infiltration rate. The time to occur the limestone dissolution, which is poorly soluble, results in products with low concentrations in the solution. Therefore, the water infiltrates the soil profile, which will cause the transportation of the particles of the corrective, of the dissolution products, and of the organic acids (Amaral et al., 2004).

Monitoring the progress of the alteration in the attributes related to soil acidity in depth in cultivated areas is fundamental to decisions regarding ways to reapply acidity corrective and whether it is necessary to revolve the soil when the transformation of the natural biomes occurs in agricultural areas. In this sense, the main objective of this study was to measure the chemical changes caused by the conventional correction of soil acidity (up to 15 cm + two gradations) in relation to the simple lime deposition on the soil surface. Secondly, it monitored whether limestones with different molar ratios of calcium and magnesium will have differential movement in the soil profile.

2. Material and methods

2.1. Description of the experiment

The experiment was carried out in October 2004 in a Typic Hapludalf soil (United States Department Of Agriculture, 2010) or Haplic Lixisol by WRB (FAO, 2014), in a natural pasture area of Bioma Campos, located in Santa Maria, Rio Grande do Sul, southern Brazil ($29^\circ 43' \text{ S } 53^\circ 42' 13'' \text{ O}$). The climate is classified as Cfa, according to the classification of Köppen, with annual average rainfall of 1769 mm and average annual temperature of 19.2° C . The actual precipitation and average monthly temperature data measured during the experiment period are shown in Fig. 1.

Before the installation of the experiment, the experimental area was maintained with the natural vegetation of the pampa biome and until then never received any cultural treatment. The surface layer soil had high active acidity, high aluminum saturation, and very low phosphorus availability (SC et al., 2016) (Table 1).

In October 2004, the natural vegetation was desiccated with

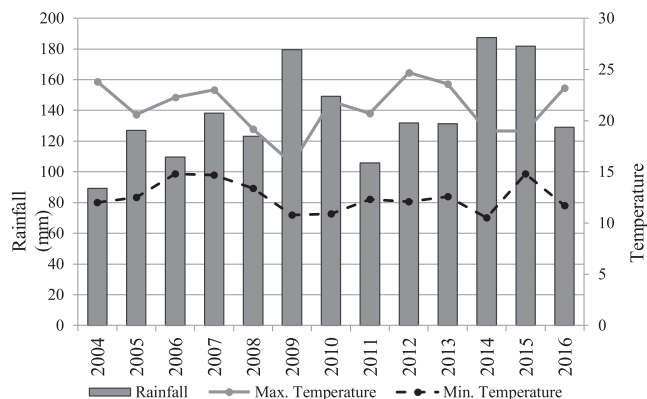


Fig. 1. Mean monthly precipitation of the municipality of Santa Maria (RS) during the period of the experiment, from 2004 to 2016.

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