

RESEARCH THE VARIATION OF EXCHANGE CALCIUM ALONG THE DEPTH OF THE SOIL PROFILE AFTER THE APPLICATION OF AMELIORANTS

Mladen ALMALIEV

Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: mladenalmaliev@abv.bg

Abstract

The effectiveness of ameliorants applied into acidic soils depends on their neutralizing power, which is determined by the calcium carbonate content and their fineness. The choice of ameliorant is a complex task, because it must be found this one which has a high neutralizing effect on easily mobile exchange aluminium, as in parallel to penetrate deeper in the soil. The use of a precipitate, as both a slow-release phosphorus fertilizer and a chemical ameliorant to neutralize acidity was theoretically and practically justified in soils with slightly to moderately acidic reaction and temperate deficiency in terms of easily mobile exchange bases in the soil. The use of hydrated lime as a chemical ameliorant in acid soils led to a relatively fast, long lasting and effective neutralization of exchange acid positions in the soil.

Key words: acid soils, calcium, hydrated lime, precipitate.

INTRODUCTION

The effectiveness of ameliorants applied into acidic soils depends on their neutralizing power, which is determined by the calcium carbonate content and their fineness (Edmeades & Ridley, 2003; Álvarez et al., 2009). However, the soil has a huge buffering capacity, which is able to reduce the effects of all kinds of changes and the process of soil acidification is accelerated by other factors such as acid rain and excessive application of ammonium nitrate (Zheng, 2010).

As a way to improve soil acidity can be the replacement of liming by surface application of more soluble materials (Castro & Crusciol, 2013), which requires the application of a limited amount of ameliorant, at a relatively shallow depth in the soil.

Chemical interventions are usually performed with prior consideration of pH values and cation exchange capacity (Joris et al., 2012). The choice of ameliorant is a complex task, because it must be found this one which has a high neutralizing effect on easily mobile exchange aluminium, as in parallel to penetrate deeper in the soil. That is why in practice is increasingly used the liming - application of calcium-containing ameliorants as hydrated lime, roasted lime, saturic lime, etc. However,

very often these ameliorants lose their effectiveness in acidic soils, on which there are already perennials, due to the low solubility and low mobility of carbonates along the depth of the soil profile (Soratto & Crusciol, 2008). One of the ways used to improve soil acidity may be to replace liming by surface application of more soluble materials (Castro & Crusciol, 2013), which requires the application of a limited amount of ameliorant, at a relatively shallow depth in the soil. This changes the main goals of the amelioration as the aim is not to neutralize the acidity, but to partially convert the exchangeable Al^{3+} and increase the levels of exchangeable Ca^{2+} in the soil.

The aim of the present study was to research the dynamics of calcium penetration along the depth of the soil profile on soils characterized by high exchange acidity by introducing calcium-containing ameliorants with different neutralizing capacity.

MATERIALS AND METHODS

The study was performed on highly eroded Chromic luvisols with differentiated profile, characterized by the presence of high exchange acidity. The experiment was set up and carried out for two years, as hydrated lime and precipitates were used as main chemical ameliorants. Hydrated lime is dried by a special

technology $\text{Ca}(\text{OH})_2$. It is a more active chemical ameliorant compared to traditionally used and relatively cheap chemical ameliorants containing CaCO_3 . Due to its high cost, this material is relatively rarely used for amelioration of acid soils, but it is a soluble compound with a higher neutralizing capacity compared to CaCO_3 . The precipitate has a weak chemical-ameliorative effect and is used primarily as a mineral citrate-soluble phosphorus fertilizer. Usually the rates in which it is applied to cover the needs of plants as fertilizer are not sufficient to neutralize the harmful acidity in the soil, but its ameliorative effect when applied in acid soils is based on its neutralizing activity. Its interaction with the soil is associated with the release of Ca^{2+} , which is due to its prophylactic chemical-ameliorative effect in acidic soils. In high Ca^{2+} deficiency, it leads to the formation of free phosphoric acid, which depending on the balance between acids and bases, dissociates into H_2PO_4^- ; HPO_4^{2-} and PO_4^{3-} , as usually the products of the three degrees of dissociation are in dynamic equilibrium with each other and reflect the momentary acid-alkaline balance and the equilibrium in the ion concentrations at the boundary between the liquid and colloidal phases. The salts of H_2PO_4^- and HPO_4^{2-} dissociate easier than hydrolyze, so the equilibrium $\text{H}_3\text{PO}_4 \leftrightarrow \text{H}^+ + \text{HPO}_4^{2-}$ is pulled to the right - a trend that is reinforced by both Ca^{2+} deficiency and phosphorus uptake in the rhizosphere. Thus, from the point of view of its influence on the acid-alkaline balance in the soil, the precipitate on the one side leads to strengthening of the weak acid positions and on the other side releases Ca^{2+} in the system of easily mobile ions (Trendafilov, 2011).

Both ameliorants were applied under the same conditions, in the same way and in the same rates. The experiment was based on the method of long plots (Shanin, 1965), as the distribution of variants were included control and three increasing rates of treatment with hydrated lime and precipitate - 100, 250 and 500 kg/ha. Each of the variants was performed in three repetitions.

After application, the ameliorants were incorporated at a depth of 18-20 cm in the soil, as before that they were homogenized by surface treatment with a top soil layer with a

depth of 10-12 cm. Soil samples were taken twice, as the first sampling was 14 months after the application of the ameliorant, and the next one 12 months later. Soil samples were taken from three layers with a depth of 0-25; 25-50 and 50-75 cm, using a soil probe, as the volume of each soil sample was composed of 3 single takes with the probe within the area of each replication. Soil samples were analyzed to establish easily mobile exchange Ca^{2+} , complexometric, by the method of Mazaeva, Neugodova and Khovanskaya (Palaveev and Totev, 1970), (BDS 17.4.4.07-97, 1997).

RESULTS AND DISCUSSIONS

Prior to field experiment, pH content potentiometric in aqueous and salt extract, easily mobile exchange Al^{3+} and H^+ and easily mobile exchange calcium was determined in order to establish the initial state of the soil. The results of the analyzes for determination the harmful acidity of the soil showed that in the terrains there was an acid reaction, relatively high content of easily mobile exchange Al^{3+} , H^+ and too high variation of easily mobile exchange Ca^{2+} and Mg^{2+} content in areas and depths. Based on the obtained results for a relatively short period of time, the degree of neutralizing effect of hydrated lime and precipitates was monitored in terms of the content of easily mobile exchange calcium. There was a necessary to develop a model by which the liming of soils contained harmful acidity and characterized by a strong deficiency of basic elements in the composition of its sorption complex to be partially or completely replaced by mineral fertilization with neutralizing fertilizers to achieve a sufficient degree of ameliorative impact in order to stabilize the acid-alkaline balance of the soil buffer systems (Valcheva, 2020).

Figure 1 shows the change in the content of exchange calcium in three depths of the study, during the two years as a response to the applied ameliorants. The average content of exchange calcium was about 8 meq per 100g/soil and as a result of the application of precipitate increased by about 1-2 meq per 100g/soil. This was an unproven but clearly manifested tendency with a high dispersion around the average values of the indicator,

which was normal in the heterogeneous environment in which it was analyzed. In practice, the acid-alkaline balance was buffered in relatively close parameters, but in clay and therefore higher absorbing soil horizons it was determined by higher ionic

concentrations. The application of the ameliorant reverses the trend. This was established only in the top soil horizon in the first year and in all studied depths in the second one.

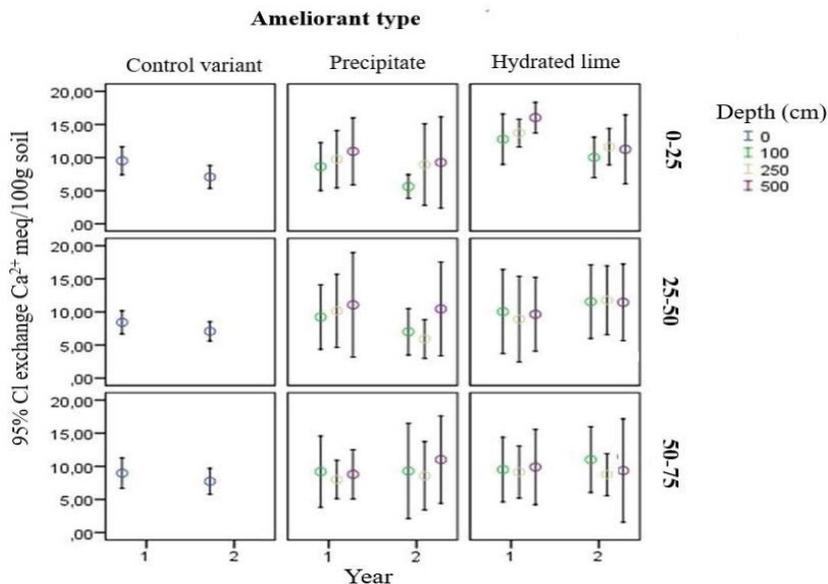


Figure 1. Distribution of calcium along the depth of the soil profile

In the second year, Ca²⁺ content decreased. Probably after the peak increase of its concentrations, established in the year of its application, part of the easily mobile calcium fills its own deficit in the more difficult to access exchange positions, thus stabilized. Part of it was absorbed on more strongly connected exchange positions in the sorption complex, and increased the relatively deeper calcium reserve of the soil, and hence it's buffering against acidification. In practice this did not change the point around which the acid-alkaline balance in the soil was situated. At the same time, the heterogeneity of the element in the soil volume increased. This was explained by the spatial heterogeneity of the environment and by the characteristic for field conditions imperfect homogenization of the ameliorant with the soil.

The application of calcium in the form of calcium precipitate in the doses and rates used for the experimental formulation did not imply a permanent and significant increase in the

content of the easily mobile form of the element in the soil, but stabilized the acid-base balance, increased the capacity of the anti-acidification buffer system and improve the conditions for mineral nutrition with this element.

When the hydrated lime was applied, it was found that with the increase of the lime rates the content of the exchange Ca²⁺ also increased, as reach values on average up to about 1,8 times higher than the initial ones. The highest concentration of easily mobile exchange Ca²⁺ was found in the top soil horizon, in the variant limed with a rate of 500 kg/ha hydrated lime. This means that the soil sorption positions had a high buffering capacity until they completely saturated with bases.

In the next experimental year, it was found a steady downward trend of reached high level of exchange Ca²⁺ in the top soil horizons of the plots, limed with rates of 250 and 500 kg/ha and increased its content in the deeper layers. There were two probable possibilities to

observe this secondary movement of Ca^{2+} along the depth of the profile. In the first case, due to the heterogeneity and positional inaccessibility of the applied lime materials with the soil particles, part of Ca^{2+} applied with the ameliorant during the first year of the study did not connect to the sorption positions. It remained in the form of $\text{Ca}(\text{OH})_2$ within the layer 0-25 cm, after that intensively leached along the depth of the profile, as saturate more the sorption complex of the deeper soil layers. The second possibility was that the strong deficit of exchange bases and the high solubility of calcium hydroxide have provided exchange connection of all applied and remained Ca^{2+} amount within the top soil layer, in which the sorption positions were saturated to a higher degree than that achieved by liming

with low and high rates, but in the deeper horizons. In this case, part of the exchange Ca^{2+} was connected to very labile positions in the complex and was desorbed later, pushed out by the ionic pressure of the acid exchange positions. When applied hydrated lime, it was found that the soil reserved a stable and equilibrium some part of the applied Ca^{2+} , probably in accordance with the capacity of the exchange sorption system. However, the application of a soluble form of lime ameliorant led to a gradual saturation of the soil, as its penetration into the depth took place in a relatively short period. The reason for this assumption was that in the second year of the study, the content of exchange calcium tends to equalize at different depths of the soil profile.

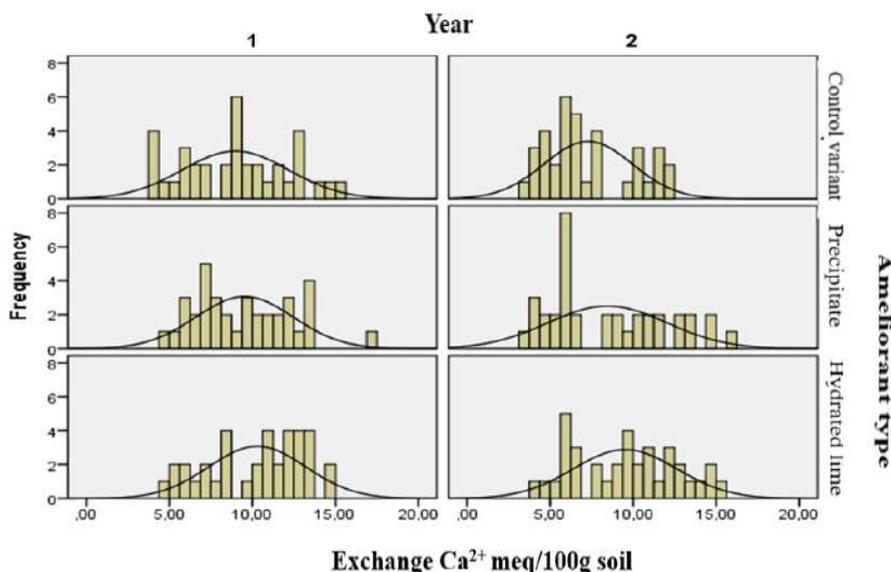


Figure 2. Characteristics of the frequency distribution of the content of exchange Ca^{2+} (meq/100g soil) along the depth of the soil profile

According to the data in Figure 2, the rates of 100 and 250 kg/da for both applied ameliorants, the frequency distribution of calcium along the depth of the soil profile was approximated to a normal level of probability of 95%.

CONCLUSIONS

The use of a precipitate, as both a slow-release phosphorus fertilizer and a chemical ameliorant to neutralize acidity was theoretically and

practically justified in soils with slightly to moderately acidic reaction and temperate deficiency in terms of easily mobile exchange bases in the soil.

Its application in the doses and rates described in the present study did not imply a permanent and significant increase of the content of the easily mobile form of the element in the soil, but stabilized the acid-alkaline balance, increased the capacity of the buffer system against acidification and created a prerequisite

for improvement the conditions for mineral nutrition with this element.

The use of hydrated lime as a chemical ameliorant in acid soils led to a relatively fast, long lasting and effective neutralization of exchange acid positions in the soil, as retain a stable and balanced some part of the applied Ca^{2+} , in accordance with the capacity of the exchange sorption system. In parallel, its penetration into the depth along the soil profile was carried out for a relatively short period, as proof of this was that in the second year of the observations, the content of exchange calcium tends to equalize at different depths of the soil profile.

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