VARIATION OF THE PARAMETERS OF HARMFUL ACIDITY IN ERODED CINNAMON FOREST SOILS (CHROMIC LUVISOLS) AND ITS RELATION WITH THE SOIL HETEROSTEITY

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Abstract

In this study, the soil acidity is characterized by pH, and content of exchangeable Al³⁺, H⁺ and Mn²⁺. It is established the content of exchangeable ions, with neutralizing in respect to harmful acidity effect - exchangeable Ca²⁺ and Mg²⁺. On the basis of the results is calculated the degree of saturation of the permanent sorption positions in soil with easily mobile bases V₃%. The latter is used as a quality criterion for characterizing the degree of need of liming of soil. The amount of neutralizing lime material is calculated based on the content of easily mobile Al³⁺, H⁺ and Mn²⁺ in meq/100g soil.

Overcoming the heterogeneity of soil, as regards to the need and rates of liming is done by application of method for geospatialization based on the distribution of sampling points in graticule.
The data for eroded cinnamon forest soil show that relatively greatest variation in soil acidity is found in the most eroded areas. In them is more pronounced spatial heterogeneity of soil in respect to easily mobile exchangeable Al³⁺, H⁺ and Mn²⁺, while as regards to the contents of easily mobile bases - Ca²⁺ and Mg²⁺ eroded areas are relatively homogenous.

Relatively greatest need of liming, based on the degree of base saturation is observed in average eroded soils, mainly in areas where illuvial clay issettled on the surface and forms relatively deep layer. Application of this ameliorative concept to full neutralization of the harmful Al³⁺ and part of the H⁺ and Mn²⁺ led to calculation of high rates of neutralization meliorants up to 6000 kg/ha.

Key words: geospatialization, liming, soil acidity, soil heterogeneity.

INTRODUCTION

Acid-alkaline equilibrium in the soil is characterized by the intensity of ion exchange between the solid, organic-mineral colloidal phase and soil solution and by the ratio of negatively and positively charged colloids, involved in ion exchange (Miroslav and Kastori, 2000). From this viewpoint, the phytotoxic effect of soil acidity on one hand is due to desorption and direct toxic effect of exchangeable Al³⁺, H⁺, and Mn²⁺ on plant roots, and on the other due to the decalcification of soil sorption positions. (Totev, 1977)

These two reasons for acid phytotoxicity of soils are distinguished so far as in the planned work is set the task to reduce the acid phytoeffect not by complete neutralization of Al³⁺, H⁺, and Mn²⁺ in exchangeable form but by adjusting the ratio between negatively and positively charged positions in the soil sorption complex, in order to prevent its acid destruction and to avoid the phytotoxic effect associated with the strong deficit of Ca²⁺ in the root active zone.

This study is part of soil amelioration survey of derelicted, because of their low natural fertility terrain in the hilly Central Eastern part of Bulgaria. The main reason for deterioration of natural fertility is the soil acidity, raised to a degree that is harmful for the main agricultural crops traditionally grown in the region-wheat, barley, maize and sunflower. Economic results obtained from this crops are unsatisfactory and in addition their crops have demonstrated a strong heterogeneity in different parts of the field. During the preliminary studies of this object it is found that the main soil ameliorative problem is soil acidity, which however is expressed in different degree within the areas of investigation. The task we set ourselves is to be defined the boundaries of soil cover heterogeneity in relation to parameters of harmful acidity and at the stage of application of chemical melioration for neutralization of
the acidity this heterogeneity to be overcome within a model for ameliorative technological applications.

MATERIALS AND METHODS

During the course of planning of soils amelioration we accepted a model for collecting soil samples in which each sample is taken from the terrain with soil probe as the sampling points are situated in square grid, regardless of the borders of soil types and local terrain topography. We studied two sections—lots 108 and 155 (Figure 1), which have complex topography and lots 113, 157 and 158 (Figure 2), where the terrain is relatively leveled and with slightly rough and monotonous relief. In both sites we take individual soil samples from three depths – 0-25, 25-50 and 50-75 cm for each point (position of sampling points is marked in Figure 1 and Figure 2). The location of points was previously mapped and coordinates were entered into the Global Positioning System—GARMIN, allowing to determine the location of each point to an accuracy of 1m.

Soil samples were analyzed to establish the pH, potentiometrically in water (Arinushkina, 1970); easily mobile and exchangeable Al\(^{3+}\) and H\(^+\), titrimetric by Sokolov (Sokolov, 1939); easy mobile exchangeable Mn\(^{2+}\), in extract with 1m KCl, as the preparation of the extract was carried out under the Laboratory system for liming of Palaveev and Totev (LSVPT-64) (Palaveev and Totev, 1970) and the determination of Mn\(^{2+}\) is by AAS (Ganey, 1990); easily mobile and exchangeable Ca\(^{2+}\) and Mg\(^{2+}\), complexometric (Arinushkina, 1970).

Figure 1. Situation and location of sampling points in lots 108 and 155
RESULTS AND DISCUSSIONS

Soil morphology

*Cinnamom forest soils (Chromic luvisols)*

Chromic luvisols, within the terrain are shallow, moderate to severe eroded. Parent material is hard, silicate, presented of highly weathered granite, metamorphites of granite and paleovolcanos. Weathering crust is shallow and most often its depth does not exceed 10-15 cm. The morphology of soil profile is typical for the cinnamon forest soils (Chromic luvisols) in the region. The surface horizon is elluvial pale, highly washed in respect of bases. Its depth ranges from 0 to about 15-18 cm. Subsoil is represented by metamorphic illuvial yellow-redish colored horizon with depth up to 40-50 cm, with heavy texture and compacted significantly.

Most shallow profiles are established in the high projecting parts of the terrain where the soil is very severe eroded and on the surface is established the transitional, illuvial-metamorphic horizon.

The structure of the surface horizon is highly powdered and in the illuvial-metamorphic horizon-lumpy-prismatic, dappled with non-carbonate skeletal material whose granulometry is characterized by rock fragments with sizes in the range of 10 to 50 mm. In the zone of most active accumulation of clay in the illuvial horizon is established strong surface gleization,
presented of stains and concretions of manganese and iron oxides.

Severe eroded leached cinnamon forest soils, shallow

The depth of the humus horizon is between 10 and 20 cm. In some parts of the terrain which have limited area humus layer is completely reduced, as a result of sheet erosion. Total depth of the soil profile is 50-60 cm. Deeper layers of the soil profile are highly skeleton. The skeletal part turns into shallow weathering crust.

Shallow leached cinnamon forest soils have limited availability for cultivation of vines. These soils may be included within the vineyard with its peripheral parts of the distribution in order not to be disturbed the overall plan of the plantation.

Soil acidity
Soil reaction – pH\(_{\text{KCl}}\)

Most of the analyzed samples are characterized with acid reaction – average pH at depth 25 cm is 4.29, at 50 cm is 4.41, and at 75 cm - 4.48.

![Figure 3. Changes in pH (KCl) by lots and depths](image)

From Figure 3 can be seen the variation of soil pH in lots. The data show that the average pH values established for the separate lots do not differ significantly. There is a trend of increasing of pH in the deeper horizons, which is especially expressed in samples from lot 113. Neutral or near-neutral pH values are determined as an exception. Histograms in Figure 4 show that the frequency distribution of pH in all lots can be approximated to the normal (Gaussian distribution). Excessive high and close to neutral pH values are determined only in lot 155.

![Figure 4. Histograms of the frequency distributions of pH](image)

The average values established for the separate lots do not differ significantly, which indicates that acid reaction of the investigated sites is characteristic for the entire area.

Content of easily mobile exchangeable Al\(^{3+}\) and H\(^+\)

Relatively high content of easily mobile aluminum and hydrogen is determined in lot 158-average 0.24 meq/100 g, as in this lot is also established the highest value of the exchange acidity, (determined by aluminum and hydrogen ions)-1.36 meq/100 g, in limit of aluminum toxicity of 0.2 meq/100 g. Values of easily mobile aluminum and hydrogen in the other lots are lower, but do not significantly differ to each other. Relatively highest is the content of aluminum and hydrogen in the surface horizon, at a depth of 0-25 cm, down the soil profile the content of these elements decreases significantly. This trend is well expressed in lots 113 and 158 (Figure 5) and in the total sample. In some cases, reduction of the exchange acidity down the soil profile is not established and it this gives a reason chemical melioration to be provided for the whole depth of the active root zone 0-75 cm, in order to avoid the negative impact of soil acidity in later period of life of the vines.

Content of easily mobile Mn\(^{2+}\)

 Studied soils in the lands of village Balabanchevo even during the morphological observation of the field showed presence of genetically differentiated profile, determining the presence of periodic surface waterlogging
during morphogenesis of the soil and hence-high content of easily mobile exchangeable manganese. The presence of redox processes in the transitional zone between eluvial and illuvial part of the soil profiles is morphologically expressed as presence of spots, dots and manganese concretions. Determined relatively high levels of exchangeable manganese in its reduced, bivalent form are an indication that the process of pseudogleization still occurs.

The distribution of bivalent manganese down the soil profile shows a clear tendency for biogenic accumulation in the surface 25 cm of the soil profile and sharply decreases in depth (Figure 6). In areas, where established are deeper, well developed and relatively slightly eroded profiles the differences in the content of exchangeable manganese in depths 25-50 and 50-75 cm are insignificant (lots 155 and 157). In other lots (108, 113 and 158) mobile manganese content decreases logically and relatively uniform in layers 0-75 cm. (Figure 6). It is known that the content of exchangeable manganese in the soil depends on both acidity and redox conditions. In analyzed samples was found that the factor "acidity" influences the content of exchangeable bivalent manganese only in surface horizons at depth of 0-25 cm. In the other depths manganese content in this form is determined by the reduction conditions and waterlogging (Figure 7).

Against the background of the values of easily mobile aluminum and hydrogen the content of exchangeable manganese in all analyzed samples is too high.

![Graph showing changes in content of exchangeable Al³⁺ and H⁺](image)

**Figure 5. Change of content of exchangeable Al³⁺ and H⁺ in extract with 1mKCl, by lots and depth**

**Content of easily mobile exchangeable Ca²⁺ and Mg²⁺**

The content of exchangeable calcium and magnesium ions in the studied lots varies quite widely. The average amount of exchangeable Ca²⁺ and Mg²⁺ in all lots of the study is relatively high-13.26 meq/100 g, but in the total sample are established values from minimum 3.97 to maximum 27.86 meq/100 g. Statistically proven, higher content of exchangeable Ca²⁺ and Mg²⁺ is established in lots 113, 157 and 158, which are united in a separate contour, but significantly lower are values in lots 108 and 155. Logically the amount of exchange Ca²⁺ and Mg²⁺ increases in depth, as the value of the increase is about 2 meq per each 25 cm down the soil profile.

The data for the average and changes in the content of easily mobile Ca²⁺ and Mg²⁺ down the soil profile are shown in Figure 8. Relatively higher levels of Ca²⁺ and Mg²⁺ in the deeper horizons, showed an increase in natural neutralizing capacity of the soil in relation to soil acidity. This is taken into account in determining of the rates of chemical meliorants, in order this natural neutralization buffering capacity of the soil to be used and thus to achieve some reduction of lime rates that should be applied.
Activities that acidify the soil

Examination of the need for liming

In order to neutralize the established in preliminary study harmful soil acidity and to prevent further soil acidification during the cultivation of vineyard it is necessary to conduct a differentiated by sections liming.

The rate of calcium oxide for liming of acid soils is calculated in order to achieve neutralization of harmful acidity and to be ensured expenditure elements in the balance of calcium in the soil. Expenditure elements in the balance of calcium, which are ensured by lime rate, are:

- Neutralization of the toxic for crops, effect of easily mobile exchangeable aluminum, hydrogen and manganese;
- Recovery of losses from utilization of calcium with plant biomass;
- Neutralization of acidification effect of mineral nitrogen fertilizers accounted for the balanced fertilization rates for period, including five years after the liming;
- Saturation of cations sorption capacity with calcium;
- Mobilization of macro and micronutrients in the soil and regulation of mineral nutrition of plants;
- Recovery of losses from leaching and compensation of positional unavailability of calcium containing chemical meliorants.

Activities for neutralization of harmful acidity in the soil

Melioration concept

The results from the analyzes of harmful acidity and lime requirements of soils indicate that the observed terrains has acid reaction, high content of exchangeable Al$^{3+}$, H$^+$, and Mn$^{2+}$ and relatively high, but too varying in separate lots and in soil depth content of exchangeable Ca$^{2+}$ and Mg$^{2+}$.

The obtained results require performance of chemical amelioration of soil in the whole area of investigation as the main activity, on which we rely to neutralize the harmful acidity and high content of manganese is liming.
Distribution of meliorants rates in the whole area of terrain

Collecting of soil samples in a square grid, allows the studied terrain to be divided into ameliorative sections with regular and convenient for mechanized scattering of lime material configuration (Figure 9 and Figure 10). Each soil sample is representative for the calculation of rate of chemical meliorants for one ameliorative lot. In ameliorative sub-lots, in which should be applied higher doses lime materials is resorted to multiple passing of spray units on the field. It is accepted maximum dose for spraying in a single pass of spray unit-1000 kg/ha.

CONCLUSIONS

The data presented in the two maps in Figure 9 and Figure 10, show that: Determined during the preliminary monitoring of the terrain heterogeneity in habitus and condition of crops is confirmed by the data for heterogeneity of the parameters of soil acidity, integrated by the calculated with the balance method lime norms for neutralizing of harmful soil acidity.

Soil sampling in a square grid allows ameliorative survey to be completed with establishment of amelioration areas with regular configuration, which allows convenient from a technological viewpoint passing of the machinery for scattering of lime materials.

Map schemes in Figure 9 and Figure 10 shows that the heterogeneity of the terrain in respect of parameters of harmful soil acidity under the conditions of homogeneous parent materials and uniform origin of soil is less dependent on the topographic complexity of the terrain.

REFERENCES

Ganev S., 1990. Modern soil chemistry. S, (Bg)
Totev T.P., 1977. The role of Al, Mn and Fe for fertility of light grey (pseudopodzolic) soil. II, Soil science and Agrochemistry, 5, (Bg).

Figure 9. Map of sub-lots for liming in lots 108 and 155

Figure 10. Map of sub-lots for liming in lots 113, 155 and 157