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Influence of Zeolite on Soil Acid Regime.

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ABSTRACT

The work is devoted to the study of influence of highly siliceous zeolite rock on acid regime of sod-podzolic light loamy soil and leached medium loamy black soil. It is established that zeolite application allows to neutralize the excess acidity of the soil greatly.
Keywords: soil acidity, sod-podzolic soil, leached black soil, zeolite.

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INTRODUCTION

The problem of soil acidity, caused by a low content of calcium and magnesium exchangeable cations, and an increased content of hydrogen ions and mobile compounds of aluminum and iron, has been and remains one of the most important problems of soil science, agrochemistry and agriculture. It is preconditioned not only by the large areas of acid soils (they are the largest in Russia - more than 50 million hectares), but also by constantly moving processes of hydrogen ions entering the soil solution due to plant decomposition with formation of organic acids, root secretions, a lot of biochemical processes, application of physiologically acid forms of mineral fertilizers, calcium removal from the plow layer, etc. [1]. Acid reaction of soil solution gradually reduces soil fertility in all its aspects (plant uptake of nutrients, activity of soil microorganisms, mineralization of organic matter, decomposition of soil minerals, dissolution of poorly soluble compounds, coagulation and peptization of colloids, toxicants getting into products).

It is well known that the essential means of soil acidity neutralizing is soil liming according to the following scheme:

$$*[SAC]H^{+} + Ca(HCO_3)_2 = [SAC]Ca^{2+} + 2H_2CO_3$$
$$H_2CO_3 \rightarrow CO_2\uparrow + H_2O$$

* soil adsorption complex

However, reduction of reclamation works, including liming, has been commonly observed in recent decades, which is accompanied by a decrease of soil fertility and, consequently, its productivity, as well as resistance of agroecosystems to unfavorable factors, primarily of anthropogenic nature. Due to these and other reasons, the search for alternative materials that can have a beneficial effect on the whole complex of soil properties and, in general, on the "soil-plant" system is currently ongoing. Silicon rocks (diatomites, zeolites, bergmeal, bentonite clays) are widely studied and proposed for use in production [2, 3, 4, 5, 6]. Thus, English scientists [7] found that the positive effect of zeolites on crop yield in field conditions is greater than that of mineral fertilizers.

A number of studies have shown a positive effect of silicon rocks, including zeolites, on soil physical and chemical properties [8]. Application of zeolite in pure form and in combination with organic and mineral fertilizers increased the pH_{KCl} value by 0,3-0,5 pH units, reduced hydrolytic acidity by 0,3-0,7 mg-eq / 100 g of soil, increased the content of phosphorus and potassium compounds available to plants in the experiments of T.F. Makeeva and M.V. Gudilina [9] on gray forest soils.

In connection with the foregoing, our research goal was to study the effect of natural high-silica zeolite rock on the acid regime of soils. To study zeolite as a material neutralizing acid reaction of soil environment, soils, contrast in origin and properties, were selected in different soil-climatic conditions: sod-podzolic and leached black soil. If the need to regulate the acidity of the first is not in doubt, as for the second, unlike sod-podzolic soils, black soil has long been considered a type of soil which does not require liming because of its high buffering.

OBJECTS AND METHODS OF RESEARCH

The research was carried out on sod-podzolic light loamy soil (experiment 1) in the conditions of Nizhny Novgorod region and leached medium loamy black soil (experiment 2) on the trial field of Ulyanovsk State Agrarian University named after P.A. Stolypin. Sod-podzolic soils are characterized by a low content of humus (1,2%), medium acid reaction (pHKCl 4,8 units), average availability of accessible phosphorus and potassium compounds (86 and 110 mg / kg according to Kirsanov); leached black soil: content of humus – 4,7%, available phosphorus and potassium (according to Chirikov) – 196 and 206 mg / kg of soil, pH_{KCl} – 5,4 units.

The scheme of experiment 1 consisted of 4 options: 1. Control, 2. Zeolite 3 tons / ha, 3. Zeolite 6 tons / ha, 4. Zeolite 12 tons / ha. It is a microfield experiment, the registration area of the plot is 1 m^2, their location is randomized, the repetition is fourfold. Zeolite was applied in autumn 2014, experimental crops: winter wheat Moskovskaya 39 (2015), barley Veles (2016) and peas Chishminsky (2017).

Experiment 2 included 8 options: 1. Control, 2. Zeolite 500 kg / ha, 3. Zeolite 2000 kg / ha, 4. Complex mineral fertilizer of azofosca $N_{60}P_{60}K_{60}$ (NPK), 5. Zeolite 500 kg / ha + NPK, 6. Zeolite 2000 kg / ha + NPK, 7. Zeolite 500 kg / ha + N_{60} (urea), 8. Zeolite 2000 kg / ha + N_{60}. Registration area of the plot is 60 m^2, repeatability is fourfold, the plots are randomized, the experimental crop is corn hybrid Voronezhsky Orzhitsa 237 MV. Analytical studies were carried out according to the corresponding State Standards on the basis of a laboratory complex of Ecological and Analytical Laboratory for Monitoring and Protection of the Environment of Minin University and a trial laboratory of Ulyanovsk State Agrarian University in threefold repetition.

RESULTS AND THEIR DISCUSSION

The results of the soil acidity study are presented in Table 1 and in the picture.

When analyzing the data of the table, first of all, a significant decrease of actual and exchange acidity in the sod-podzolic soil in case of zeolite application is seen, which reaches its maximum at a dose of the latter of 6 t / ha and is, on average, 1,11 and 0,48 pH units in the period of 3 years. The neutralizing effect of zeolite on the acid properties of the soil is undoubtedly due to high content of calcium (13,3% CaO) and magnesium (1,9% MgO); from 319 kg / ha to 1276 kg / ha of Ca^{2+} and Mg^{2+} get into the soil. Apparently, the introduction of 6 tons of zeolite together with calcium and magnesium is quite enough to neutralize the exchange acidity for a given time period (3 years). As for hydrolytic acidity, which includes all hydrogen-containing ions in the soil (not only highly-mobile, but also more firmly retained in the diffuse layer of colloidal micelles), as well as cations of aluminum (Al^{3+}) and iron (Fe^{2+}, Fe^{3+}), their neutralization requires a greater number of exchangeable cations and a longer period of time. This is evident by the maximum decrease of hydrolytic soil acidity in the variant with a zeolite dose of 12 tons / ha and the content of mobile aluminum compounds. On average for 3 years, the hydrolytic acidity in sod-podzolic soil decreased by 0,33 mg-eq / 100 g of soil, mobile aluminum by 0,46 mg / 100 g of soil.

Table 1: Effect of zeolite on the acidity of sod-podzolic light loamy soil

Variant	2015	2016	2017	On average for 3 years	± to control
Actual acidity, pH_{hydr} units					
Control	5,88	5,96	5,92	5,92	-
Zeolite 3 tons / ha	6,54	6,66	6,71	6,64	+0,72
Zeolite 6 tons / ha	6,97	7,03	7,09	7,03	+1,11
Zeolite 12 tons / ha	6,93	6,99	7,04	6,99	+1,07
HCP_{05}	0,31	0,34	0,15	-	-
Exchange acidity, pH_{KCl} units					
Control	4,81	4,90	4,86	4,86	-
Zeolite 3 tons / ha	5,04	5,17	5,27	5,16	+0,30
Zeolite 6 tons / ha	5,21	5,31	5,49	5,34	+0,48
Zeolite 12 tons / ha	5,16	5,28	5,36	5,27	+0,41
HCP_{05}	0,35	0,09	0,27	-	-
Hydrolytic acidity, H_h, mg-eq / 100 g of soil					
Control	2,84	2,75	2,82	2,80	-
Zeolite 3 tons / ha	2,76	2,61	2,67	2,68	-0,12
Zeolite 6 tons / ha	2,60	2,49	2,55	2,55	-0,25
Zeolite 12 tons / ha	2,52	2,41	2,49	2,47	-0,33
HCP_{05}	0,06	0,09	0,09	-	-

A similar neutralizing effect of zeolite on the acid regime was also observed on black soil with a slightly acidic reaction. Application of zeolite for corn fertilization system at a dose of only 500 kg / ha ensured a shift of exchange acidity by 0,12, and at a dose of 2000 kg / ha by 0,32 units and the soil acquired a reaction of soil solution close to neutral. Accordingly, the hydrolytic acidity decreased by 0,32 and 0,52 mg-eq / 100 g of soil. The neutralizing effect of zeolite remained when it was combined with mineral fertilizers at the doses of NPK of 60 kg of active substance per hectare.

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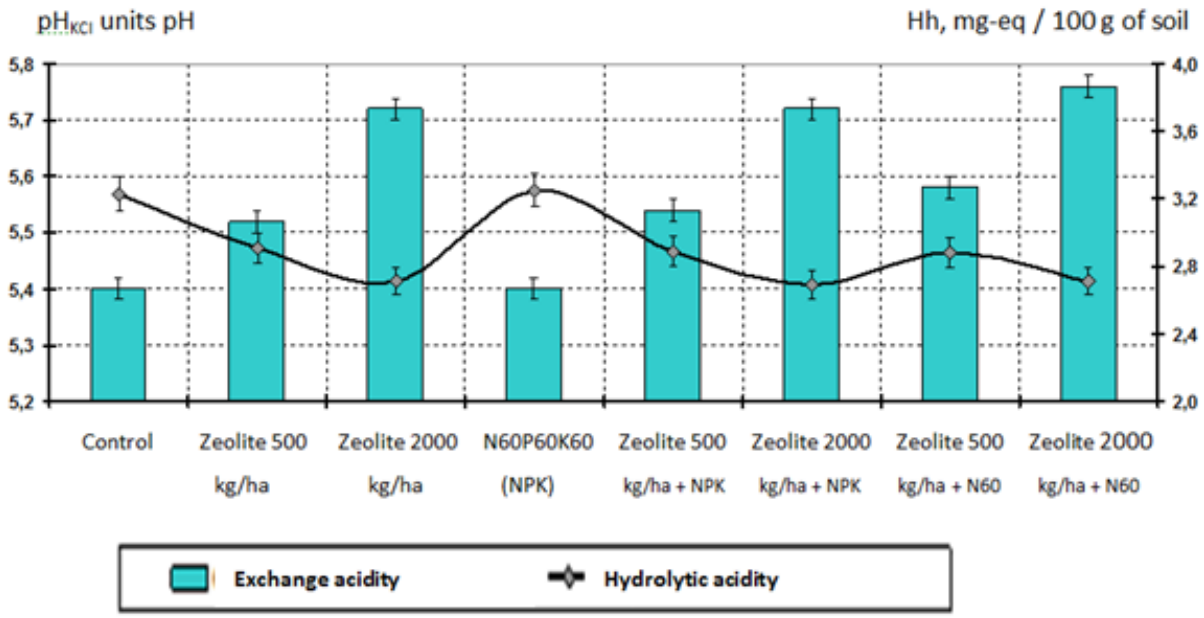

Picture: Effect of zeolite on the acid regime of leached black soil

The obtained results on the study of the effect of zeolite on the acid regime are comparable to the effectiveness of liming of these soils. Table 2 shows the changes of the acidity of leached black soil on the experimental field of Ulyanovsk State Agrarian University in case of its liming.

Table 2: Effect of liming on the reaction of soil solution of leached black soil

Variant	Exchange acidity		Hydrolytic acidity	
	pH_{KCl}, units.	± to control	H_h, mg-eq / 100 g	± to control
Control	5,47	-	3,43	-
$CaCO_3$ 2 t/ha	5,54	+0,07	3,18	-0,25
$CaCO_3$ 4 t/ha	5,53	+0,06	3,21	-0,22
$CaCO_3$ 6 t/ha	5,61	+0,14	2,97	-0,46
HCP_{05}	0,07		0,15	

The analysis of the results shows that the neutralizing effect of zeolite at compared doses exceeds the neutralizing effect of liming material on acidity of leached black soil.

CONCLUSION

As a result of the conducted studies, positive effect of zeolite on parameters of soil acid regime was established. The application of 6 tons of zeolite per hectare contributed most to reduction of actual acidity of sod-podzolic loamy soil (by 20%), exchange acidity – by 13%, and by 60% – to an increase of ion exchange of the 'soil-solution' system, this effect was kept during the 3 years of research. Similar trends were observed on leached black soil with subacid reaction of soil solution: the shift of exchange acidity was 0,12 (dose of zeolite 500 kg / ha) and 0,32 (dose of zeolite 2000 kg / ha) units of pH_{KCl} with a significant decrease of hydrolytic acidity 0,32 and 0,52 mg-eq / 100 g of soil). Thus, the positive effect of neutralizing of soil acidity excess, compared to liming at appropriate doses, allows us to consider the use of zeolite not only as a silicate fertilizer, but also as a meliorative method.

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