

Differentiation of physicochemical parameters and productivity of sod-podzolic soil owing to long application of different fertilizer systems and doze of lime

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The purpose. To determine dependences of prolonged application of fertilizer systems and chalking by various dozes of CaCO_3 on the content of humus and physical and chemical properties of sod-podzolic cohesive sand soil and its productivity. **Methods.** Field experiment, laboratory researches, systems analysis, estimation-comparative. **Results.** Data are given of long researches (1980–2015) in studying influence of organic and organic-and-mineral fertilizer systems in crop rotation and of various dozes of lime on the total yield of grain units, content of humus, potential and hydrolytic acidity, base exchange capacity, sum of the absorbed bases and saturation capacity by them of sod-podzolic cohesive sand soil. **Conclusions.** Application during 35 years on sour sod-podzolic soil of organic and organic-and-mineral fertilizer systems without chalking has not provided growth of content of humus. Combination of organo-mineral fertilizer and chalking with simultaneous increase of dozes of CaCO_3 led to increased content of humus and improvement of physical and chemical characteristics of soil. The greatest total yield of grain units was gained at entering 1,5 dozes of lime on the background of organic-and-mineral fertilizer system.

Key words: soil, chalking, fertilizer system, acidity, base exchange capacity, humus, grain units.

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The soil cover of the Polissia of Ukraine is represented mainly by light in granulometric texture sod-podzol soils with a low content of humus and nutrients and unsatisfactory physical and chemical indicators, which significantly limits the possibility of maintaining cost-effective plant cultivation on them. The top-priority measure in radically improving of acidic soils is liming.

The economic efficiency of the chemical melioration of acidic soils is largely determined by the doses of lime, the continuance of their effect, and the relationship between the costs of liming and the secondary value of crop yields during the period of its stable effect.

However, works that cover experimental data on the effects of various doses of lime, taking into account their continuous aftereffects on humus content and physicochemical properties and soil productivity in Ukraine, are published extremely rarely due to the very limited number of stationary experiments in which these issues can be studied.

Analysis of recent research and publications. The increase in productivity of acidic soils after their liming is due primarily to the improvement of physical and chemical properties, which is a prerequisite for increasing the content of humus, nutrients and activation of microbiological activity [1, 2, 3, 4, 5].

In the question of liming, the study of influence of different doses of chemical ameliorants on the content of humus in soils and their physical and chemical parameters is relevant. Numerous results of studies indicate that liming in combination with organo-mineral fertilization system contributes to its accumulation in the soil [6, 7, 8].

The whole complex of acidic soils physicochemical parameters is significantly improved owing to liming of these soils: the potential and hydrolytic acidity decrease, the capacity of cations absorption increases, total absorbed bases and their saturation increase [9, 10, 11].

The degree and continuance of liming effect on the properties of soils primarily depends on the doses of CaCO_3 . From a theoretical and applied point of view, it is important to establish the relationship between these factors, which is important for the better understanding of the development of soil processes in time owing to influence of different doses of ameliorant and for the use of new knowledge in the preparation of practical recommendations on the liming of acidic soils.

The purpose of the research is to determine the dependence of the influence of the continuous application of fertilization systems and liming with different doses of CaCO_3 on the content of humus and on the physicochemical properties of sod-podzol clayed sand soil and its productivity.

Materials and methods. The research was conducted in a long-term stationary field experiment, laid on the lands of the Institute of Agriculture of the Western Polissia of NAAS in 1979.

The soil of the experimental field is sod-podzol clayed sand. Before the trial establishment, soil was characterized by the following indicators: the content of humus – 0,86–0,97%, mobile forms of phosphorus and potassium by Kirsanov are 109–139 and 55–81 mg/kg of soil, respectively, pH – 4,6–4,8; the hydrolytic acidity and total absorbed bases are 2.3 and 2.8 mg equivalents/100 g of soil, respectively. The total area of the experimental field is 198 m², registration – 100 m², replication is the three-stage. Experiment design is given in the table number 1. Farming culture is commonly used for this zone.

Mineral fertilizers were used in the recommended norms for crops.

The main liming of the soil was carried out at the beginning of the experiment, and after the first and second crop rotations they were repeated. Lime was applied in doses provided by the experimental design. Doses of CaCO_3 were calculated on the basis of hydrolytic acidity.

The analytical work was carried out in the analytical laboratory of the Institute of Agriculture of Western Polissia of the NAAS of Ukraine, as certified by the Vinnitsa Center "AgroStandard", by the following methods: humus – by I. V. Turin in the modification of V. M. Simakov; pH of the salt extract – by the potentiometric method (DSTU ISO 10390–2001); hydrolytic acidity – by the method of Kappen (GOST 26212–91), the total absorbed bases – by the method of Kappen-Hilkovyc (GOST 27821–88); mobile compounds of phosphorus and potassium – by the method of Kirsanov (DSTU 4405–2005).

Field studies were conducted using field experiment method by B. A. Dospekhov (1985).

Results. Most of the agronomically important properties of the soil depend on the content of humus in it, its stocks and qualitative composition.

Sod-podzol soils are naturally poor in humus; therefore, a steady increase in the yield of agricultural crops on them is possible only with the expanded reproduction of its reserves.

The results of research show that after 35 years of application of organic and organo-mineral fertilization systems without soil liming, the content of humus in it was the same – 0,83% (table 1). The lack of humus accumulation in these variants compared with the initial data is primarily due to the peptization of some of the newly formed humus substances in the acidic environment and the washing of them from the arable layer [1].

Liming of soil radically changes the direction of transformation of organic matter, reducing the mobility of humus, which contributes to the growth of its content. The experimental data obtained show that the content of humus in the soil increased with increasing doses of CaCO_3 . In particular, the introduction of 0.5 doses of lime by hydrolytic acidity on the organo-mineral background of fertilization caused an increase in the content of humus compared with the background from 0.83 to 0.88 %. An increase in the dose of CaCO_3 to 1.0 dose contributed to an increase in the humus content to 0.96 %. At the introduction of 1.5 and 2.0 doses of lime in combination with the organo-mineral fertilization systems, the content of humus increased to 1.06 and 1.09 %, respectively.

The experimental data obtained also allow us to determine the effect of the continuous application of various fertilization and liming systems on the physical and chemical properties of the soil. Analysis of the results of the change of the soil solution reaction owing to the influence of these factors shows that at organic fertilization system the acidity of the soil solution at the end of the research period was 4.4 pH. Addition of this fertilization system by application of recommended norms of mineral fertilizers caused even more acidification of soil – 4,2 pH.

1. Humus content and physicochemical indicators of sod-podzol soils after continuous (1980-2015) application of various fertilization systems and doses of CaCO₃

Variant	Humus, %	pH	Hr, mg-eq/100 g of soil	Base exchange capacity, mg-eq/100 g of soil	Total absorbed bases, mg-eq/100 g of soil	Base saturation, %
Manure – 17 t/ha (1980-2005), straw (2006-2015)	0,83	4,4	2,65	4,05	1,6	39,5
NPK + manure – 17 t/ha (1980-2005), straw (2006-2015) – background	0,83	4,2	2,80	4,0	1,2	30,0
Background + CaCO ₃ (0,5 Hr before trial establishment and after I and II rotation)	0,88	4,7	2,27	4,67	2,4	51,1
Background + CaCO ₃ (1,0 Hr before trial establishment and after I and II rotation)	0,96	5,1	2,10	5,00	2,9	55,3
Background + CaCO ₃ (1,5 Hr before trial establishment and after I and II rotation)	1,06	5,6	1,97	5,32	3,4	63,9
Background + CaCO ₃ (2,0 Hr before trial establishment and after I and II rotation)	1,09	5,7	1,40	5,40	4,0	73,0

At the end of this period, at the application of 0.5; 1.0; 1.5 and 2.0 doses of CaCO₃ the acidity of soil solution was 4.7; 5.1; 5.6 and 5.7, respectively. The data presented show that on the 19th year of the aftereffect of 1.5 and 2.0 doses of CaCO₃, the soil solution reaction was in the favorable range for most agricultural crops. The results obtained lead to the necessity of compulsory consideration of the factor of the continuance effect of various doses of lime in the process of determining their comparative economic efficiency. After all, higher financial costs of liming by higher doses of CaCO₃ compared to smaller ones can be offset by a longer effect of the first.

Changes in hydrolytic acidity, depending on fertilization systems and doses of lime, had the same pattern as the exchange acidity. After the end of the research period (1980–2015), its indicators at

the organic and organo-mineral fertilization systems without soil liming were 2.65 and 2.80 mg-eq/100 g of soil, respectively, that is, the addition of organic fertilization system with mineral fertilizers was accompanied by growth of hydrolytic acidity.

The liming of the soil significantly affected the potential acidity. It is natural that as the amount of the reclaimed ameliorant increased, it decreased. Thus, the application of 0.5; 1.0; 1.5 and 2.0 doses of CaCO₃ compatible with the organo-mineral fertilization system resulted in a decreasing of hydrolytic acidity to 2.27; 2.10; 1.97 and 1.40 mg-eq/100 g of soil, respectively, which is 18.9; 25.0; 30.0 and 5.0 % less compared to the background.

One of the basic criteria of assessing the level of potential and effective fertility is the base exchange capacity. According to the results of our research, in the variant of long-term application of the organic fertilization system, the base exchange capacity was 4.5 mg-eq/100 g of soil. Addition of the organic fertilization system by the application of recommended average norms of mineral fertilizers did not lead to a significant change in this indicator. The liming of the soil on the background of the organo-mineral fertilization system has caused a significant increase in the base exchange capacity of sod-podzol clayed sand soil. At the same time, there was a clear pattern of increasing the base exchange capacity with increasing doses of CaCO₃. In particular, application of 0.5; 1.0; 1.5; 2.0 doses of CaCO₃ resulted in an increasing the base exchange capacity of 16; 25; 33 and 35%, respectively, which, in addition to other factors, may be due to the improvement of soil humus content.

Fertilizers and chemical ameliorants affect not only the base exchange capacity, but also the composition of the absorbed bases. Of these, calcium and magnesium play an extremely important influence on the beneficial properties of soils and on the conditions of plant growth. First of all, they coagulate organic and mineral colloids, ensuring their better preservation and accumulation, which is the basis for increasing the soil fertility.

The data obtained in the research show that the continuous use of different fertilization systems and different doses of CaCO₃ essentially affects the total absorbed bases. It was 1.6 mg-eq/100 g of soil at the organic fertilization system. The addition of organic fertilizers by mineral in recommended doses at continuous use led to a decrease in the amount of total absorbed bases to 1.2 mg-eq/100 g of soil. The soil liming in proportion to the increasing doses of CaCO₃ resulted in a corresponding increase in the content of the bases in it. At the application of 0.5; 1.0; 1.5 and 2.0 doses of CaCO₃ the total absorbed bases increased to 2.4; 2.9; 3.4 and 4.0 mg-eq/100 g of soil, respectively.

To characterize the soil, it is important to know both the total absorbed bases and their correlation in the soil absorption complex with hydrogen ions. After all, soils with the same total absorbed bases can have varying degrees of base saturation and need for liming. At the continuous crops cultivation using organic and organo-mineral fertilization systems, the degree of base saturation of sod-podzol clayed sand soil was very low and amounted to 39.5 and 30.0 %, respectively. Lime introduction improved the base saturation. Application of 0.5; 1.0; 1.5 and 2.0 doses of CaCO₃ before the trial establishment and after the first and second crop rotations caused such significant changes in the soil absorption complex, which were clearly manifested after the end of the fifth rotation. In particular, at the application of studied doses of CaCO₃, the degree of base saturation of the soil at that time was 51.1; 55.3; 63.9 and 73.0 %, respectively.

Taking into account the continuous effect of liming on the soil properties and crops yield, the most objective index of its agronomic efficiency is the growth of the total soil productivity over the entire period of its effect.

2. Productivity of crop rotation depending on fertilization and doses of CaCO₃

Variant	Total crop	Liming related	Mineral fertilization
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	rotation productivity (1980-2015), t/ha, g.un.	increase		and liming related increase	
		± t/ha, g.un.	%	± t/ha, g.un.	%
Manure – 17 t/ha (1980-2005), straw (2006-2015)	113,4	-	-	-	-
NPK + manure – 17 t/ha (1980-2005), straw (2006-2015 pp.) – background	141,4	-	-	28,0	24,7
Background + CaCO ₃ (0,5 Hr before trial establishment and after I and II rotation)	174,3	32,9	23,2	60,9	53,7
Background + CaCO ₃ (1,0 Hr before trial establishment and after I and II rotation)	188,6	47,2	33,2	75,2	66,3
Background + CaCO ₃ (1,5 Hr before trial establishment and after I and II rotation)	194,2	52,8	37,2	80,8	71,2
Background + CaCO ₃ (2,0 Hr before trial establishment and after I and II rotation)	193,2	52,2	36,7	80,2	70,7

The obtained results show that the application of the recommended norms of mineral fertilizers on acidic soils without liming is not sufficient to increase their productivity to a high level. Thus, at the combination of the organic fertilization system with application of mineral fertilizers, the gathering of grain harvest units for entire period of research increased from 113.4 to 141.4 t/ha or 24.7%, however, on an annual basis it was low and amounted to only 4.04 t/ha (table 2).

Soil liming with 0.5; 1.0; 1.5 and 2.0 doses of CaCO₃ against the background of the organo-mineral fertilization system resulted in an increase in soil productivity of 23.2; 33.2; 37.2 and 36.7%, respectively.

In modern agriculture, the highest yield is achieved through the use of the effect of interaction of various factors. The analysis of the experimental data obtained shows a very high efficiency of liming in conjunction with the organo-mineral fertilization system. Without liming, it increased the gathering of grain harvest units of 24.7%, and in the complex with the introduction of 0.5; 1.0; 1.5 and 2.0 doses of CaCO₃ it increased grain harvest units of 53.7; 66.3; 71.2 and 70.7%, respectively. For 35 years of research, the highest harvest of grain units is 194.2 t/ha, obtained at the liming of sod-podzol soils with 1.5 doses of CaCO₃ against the background of organo-mineral fertilization system.

Thus, liming of acidic soils in combination with the use of organo-mineral fertilizers can significantly increase their productivity and is the most important condition for their highly effective use.

Conclusions

The application of organic and organo-mineral fertilization systems without liming for 35 years on acidic sod-podzolic soils did not increase the content of humus. At the application of 0.5; 1.0; 1.5 and 2.0 doses of lime, calculated by the hydrolytic acidity, on the organo-mineral fertilization system background the humus content increased to 0.88; 0.96; 1.06 and 1.09 %, respectively, compared with 0.83% on the background.

After 19 years of the last liming, the best physicochemical parameters of soil: pH – 5.6 and 5.7; Hr – 1.97 and 1.40; total absorbed bases – 3,4–4,0 mg-eq/100 g of soil; base exchange capacity – 5,32 and 5,40 mg-eq/100 g of soil; bases saturation – 63,9 and 73,0 % provided the liming of 1,5 and 2,0 doses of CaCO₃, respectively. The largest total yield of grain units for the 35 years is 194.2 t/ha, which is 71.2 % more compared with the control, received at the application of 1.5 doses of lime in conjunction with the organo-mineral fertilization system. At the same time, liming related increase the crop rotation productivity was 37.2%.

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