

Influence of liming at different fertilizer systems in crop rotation on balance of humus of grey forest soil**G. Mazur, Academician of the NAAS, Doctor of Agricultural Sciences****M. Tkachenko, doctor of agricultural sciences****V. Shkliar, National Scientific Center "Institute of Agriculture of NAAS"**

The purpose. To investigate long influence of chemical amelioration at different fertilizer systems on balance of humus of grey forest soil and its influence upon efficiency of crop rotation. **Methods.** Field and laboratory experiment, comparative-analytical, correlative-regression. **Results.** Results of long influence of liming are brought at different fertilizer systems upon balance of humus and efficiency of cultures of crop rotation which is closely connected to change of humus condition of grey forest soil. **Conclusions.** Close correlation links of calculated balance of humus with actual change of content of general humus in arable layer of grey forest soil are determined: at different fertilizer systems and liming (0,876), and with average efficiency of cultures of crop rotation (0,825) at determination accordingly 77% and 68,1%.

Key words: *balance of humus, grey forest soil, chemical amelioration, fertilizer system, efficiency of crop rotation, fertility.*

Getting high and stable yields of crops is possible only with a certain level of humus in soil and ensuring the deficit-free balance of organic matter in it through which primarily supported the intensity of the flow of matter and energy in farming systems.

The optimal humus content is set for each soil type. So, for sandy soils it is, according to G. A. Mazur [1], 1.6 - 1.8 %. According to B. S. Nosok [2] for gray forest sandy loam soil - 2,0-2,5, dark gray forest and chernozems – 2,8-3,3, chernozem typical – 3,7-4,2 %. For such humus content, a stable fertility level is provided for each of the listed types of soils. To achieve optimal humus content, soil should be replenished annually with the required amount of organic matter, and with the content close to optimal, ensure its deficit-free balance.

The basis for reproduction of soil fertility is the provision of a deficit-free humus balance in it, which positively affects most of the soil properties and its fertility. Humus in the soil serves as the coordinator of systematic processes and modes, provides the vital functions of the microflora, favorable conditions and availability of nutrients for plants, accelerates the circulation of substances and the energy level of processes in the soil and plant [3, 4].

The intensive use of agricultural lands without sufficient organic fertilizers, which has been observed recently, leads to dehumidification of soils, their degradation and reduced fertility [5, 1]. One of the main problems of agricultural production is, of course, the preservation and increase of soil fertility by adjusting the balance of humus. The main reasons for lowering humus content are well-known. First of all, they are related to the decrease in the flow of fresh organic matter into the soil due to the exclusion of a significant part of the biomass with the harvest and a sharp decline in the production of traditional organic fertilizers [6].

In gray forest soils there are significant signs of their high acidity [7, 1, 8]. They are, by nature, inclined to degrade their properties quickly. Saturation of crop rotation by fertile crops, intensive cultivation and the use of only mineral fertilizers are very common factors of soil fertility loss in modern conditions. They contribute to enhanced mineralization of organic substances that negatively affect the structure of the soil-absorbing complex and increase the acidity of the soil [9, 10, 1, 11].

The primary measure of radical improvement of fertility of acid soils and obtaining sustainable agricultural yields is a chemical reclamation. The limestone fertilizer that is introduced into the soil neutralizes excess acidity, improves the physical and chemical properties of the soil, provides plants with calcium and magnesium, activates microbiological processes, increases the fertility efficiency and productivity of crop rotation, which ultimately affects the total content of humus in the soil [12, 1].

Studies conducted in the agropedology department of NSC "Institute of Agriculture NAAS" [13, 1] showed that keeping potential reserves of humus provided only by equivalent return of the lost nutrients, allowing to maintain fertility at baseline, because without fertilizer loss of humus in gray soil is up to 0,25-0,30 t/ha. The increase of humus formation in gray soil is achieved by the combined application of 10 t/ha manure (5-6 t/ha of by-products with siderate), 160 kg/ha NPK with liming 1,0 Hg.

The study of the influence of various fertilizer systems on humus content is widely studied abroad. In the long-term field experiment in the United States [14], limes and fertilizers were introduced since 1955 to areas that had not been previously fertilized. The results of this experiment indicate that the content of organic matter in the soil on fertilized areas increased compared to areas where fertilizers were not used, which is explained by the increase in yields of cultivated crops in fertilized areas, and thus increase the number of crop-root residues that remain in the soil. Research scientists of Lithuania [15] found, that the organic fertilizer, which was introduced into the loamy soil during the 5 rotations of crop rotation, had a positive effect on the content of humus in the upper layer under different fertilizing systems. In particular, under the organic-mineral fertilizer application system 40, 60 i 80 t/ha of manure, the content of humus in the upper layer increased accordingly by 13,1, 16,2 and 14,6 %, while for an organic fertilizer system (80 t/ha of manure) its content increased by 10.1%, compared with the variant without fertilizers. In a long-term field experiment in Germany, studies were conducted on the effects of the use of three different levels of nitrogen introduction on humus content. The researchers found that increasing the level of mineral nutrition did not lead to an increase in the content of organic matter in the soil, although small fluctuations in its content occurred within 10 years before the equilibrium condition was achieved. During the first 6 years, changes in the humus content were notable when comparing the mineral system with the organo-mineral fertilizer system, which, moreover, had variants with different initial values of the content of organic matter in the soil. There was a decrease in the content of humus in variants using only mineral fertilizers and to a greater extent in those areas where the initial content of organic matter was higher [16].

The solution of the problem of effective soil fertility management and the yield of high quality crops is closely linked to the change in the humus state based on the search for additional sources of organic matter, ways of their optimal transformation, environmentally safe application of the required amount of mineral fertilizers and chemical meliorants [17, 18]. In view of this, it is important to evaluate the impact of various agronomic fertility reproduction measures on the transformation of organic matter in the soil.

The purpose of the research - investigate the long-term effects of chemical melioration under different fertilizer systems on the balance of humus in gray forest soil and its relationship with crop rotation productivity.

Materials and methods of research. The research was conducted in 1992-2015 at the NSC "Institute of Agriculture of NAAS". A stationary experiment, was founded in 1992 on a gray forest soil. Initial indicators of soil fertility parameters (0-20 cm): pH_{KCl} (potentiometric method) – 4,6, hydrolytic acidity (by the Kappen method) – 3,6 mg-eq/100 g soil, exchange calcium and magnesium (atomic absorption method on a spectrophotometer AAS-3) – respectively 3,9 and 0,58 mg-eq/100 g soil. The research was carried out in grain-grass-cultivating crop rotation with such a set of crops: oat mix, winter wheat, sugar beet, barley with sowings of clover, clover, winter wheat, corn silage. The fertilizer system included two levels of organic and three levels of mineral fertilizers. Organic fertilizers were added to sugar beet and corn to silage (only in the first rotation of crop rotation) at a dose of 35 and 52 t/ha of manure, which means on 1 hectare of crop rotation area was 10 and 15 t/ha. Mineral fertilizers per 1 hectare of crop rotational area by the content of the active substance were: single dose – $N_{54}P_{54}K_{56}$, moderate – $N_{80}P_{80}K_{85}$, increased – $N_{108}P_{108}K_{112}$. The lime in the form of limestone and dolomite flour was introduced in the year of growing oat mix (spring 1992) in forms and doses in accordance with the experimental scheme and the initial hydrolytic acidity of the soil. Since 2006 (beginning of the third rotation of crop rotation), reconstruction of the experiment was carried out. Organic fertilizers were introduced into the soil in the form of green mass of the clover (starting in 2010) and by-products (no tradable part of the harvest of spring and winter wheat, soybean and millet), introduced in the year of growing these crops. Mineral fertilizers were introduced at the level $N_{52}P_{28}K_{52}$ (single dose), $N_{78}P_{42}K_{78}$ (moderate dose) i $N_{104}P_{56}K_{104}$ (increase dose) per 1 hectare of crop rotation area. Lime in the form of a defecate with contents of $CaCO_3$ near 50 % were added by the amount of hydrolytic acidity with a full dose 1,0 Hg – 4,5-6,0 t/ha $CaCO_3$, 1,5 Hg - 7,3 t/ha $CaCO_3$. Crop rotation was introduced: soybeans, wheat, barley, clover, barley + clover, green clover (2nd slope on siderate), winter wheat, millet. Repeatability of the experiment is 4 times, the area of the crop area is 60 m² (10×6), accounted – 24 m² (6×4). The analytical work was carried out at the Laboratory of Agropedology of the NSC "IZ NAAN" by the following methods: the total content of humus - by the method of I.V. Tyurin in the modification of V. M. Simakov, burning by B. A. Nikitin (DSTU 4289: 2004); The yields of the main products and by-products were determined annually from each accounting site, the weight of the grain was converted to 1 hectare taking into account the contamination; To estimate the humus balance in the soil of crop rotation using different fertilizer and liming systems using the method, which is set out in scientific and methodical work "Calculation of balance of humus and nutrients in agriculture of Ukraine at different levels of management" [19]. Also, a comparison

was made between the theoretically calculated humus balance and the change in its actual content in the arable and sub-soils of the soil.

The research results indicate (Table 1), the balance of humus in the control variant (without fertilizers) were scarce, and humus loss in 24 years were 1.71 t/ha. In the variant, where only the total dosage of liming (var. 2) was carried out with hydrolytic acidity, and in the variant where only mineral fertilizers were applied in a single dose (var. 3), a gradual accumulation of humus occurred due to an increase in the yield of agricultural crops, respectively to 1.75 and 4.25 t/ha for the research period.

It is known that the use of mineral fertilizers contributes to the increase of yields and, accordingly: an increase in the yield of by-products, poplar-root residuals and is a prerequisite for their rapid expansion in soil. So, in variants where mineral fertilizers were introduced in moderate (var 18) and elevated (var 19) doses on the background of liming (1.0 Hg), the growth of humus exceeded its losses for mineralization, and the growth was 9.18 and 10.83 t/ha. Using manure (green manure) on the background of liming full dose by hydrolytic acidity contributed to increasing stocks of humus to 7.55 t/ha.

Under conditions of intensification of agriculture and deficit of organic fertilizers, one of the reserves for achieving a positive balance of humus is by-product, as a source of soil replenishment with raw organic mass. Thus, in variant 16, where the sowing of the siderate was combined with the use of by-products, the balance of humus was positive, and the growth was 10.2 t / ha.

On the yield and mass of plant residues, which are the source of newly formed humus, have a significant effect of organic and mineral fertilizers introduction with different doses of hydrolytic acidity. The best developed plants under the influence of organic fertilizers and meliorants, which have a positive effect on the physical and chemical parameters of the fertility of gray forest soils, leave more of the popliteal and root residuals, resulting that the process of humification prevailing over the mineralization process. The higher yield on the background of the introduction of increased doses of mineral fertilizers, compared with control, positively affects the flow of fresh organic matter, there is not only a direct relationship between the humus state and the harvest, but also the feedback, the high yield due to plant remains affects the balance of humus in the soil.

1. Humus balance in gray forest soil due to chemical melioration and various fertilizer systems in crop rotation (for 24 years), t/ha

Variant	Loss of humus from mineralization	Formation of humus			Humus balance (+, -)
		Total	Due to		
			Plant residues	Organic fertilizers	
1 - No fertilizer (control)	29,19	27,48	27,48	0	-1,71
2 - CaCO ₃ (1,0 Hg)	29,19	30,94	30,83	0,12	1,75
3 - NPK	29,19	33,44	33,44	0	4,25
5 – Manure (green manure) + CaCO ₃ (1,0 Hg)	29,19	36,74	32,66	4,09	7,55
6 - Manure (green manure + by-products) + NPK - Background	29,19	45,55	41,53	4,01	16,36
7 - Background + CaCO ₃ (1,0 Hg)	29,19	48,35	44,18	4,17	19,16
8 - Background + dolomite (1,0 Hg)	29,19	48,48	44,44	4,03	19,29
13 - 2 NPK + CaCO ₃ (1,0 Hg) + manure (green manure + by-products)	29,19	51,19	46,98	4,21	22
14 - 1,5 NPK + CaCO ₃ (1,5 Hg) + manure (green manure + by-products)	29,19	50,94	46,67	4,28	21,75

15 - 1,5 NPK + CaCO ₃ (1,0 Hg) + manure + by-products (green manure)	29,19	52,27	48,07	4,2	23,08
16 - BP - By-products + (green manure)	29,19	39,39	39,18	0,22	10,2
18 - 1,5 NPK + CaCO ₃ (1,0 Hg)	29,19	38,37	38,25	0,13	9,18
19 - 2 NPK + CaCO ₃ (1,0 Hg)	29,19	40,02	39,87	0,15	10,83

Thus, in variants with application of mineral fertilizers in moderate doses in combination with organic (manure or by-products and siderate) on the background of liming by various types of meliorants (defecate, dolomite flour), the growth of humus was 19,16-19,29 t/ha, whereas, for the same fertilizers, but without periodic chemical reclamation - 16.36 t/ha.

2. Changes in the content of total humus in arable layer of gray forest soil, depending on liming and various fertilizer systems in crop rotation, %

Variant	Humus content, %		
	Output indicators (1992)	After 24 years of research (2015)	± to output indicators
1 - No fertilizer (control)	1,34	1,19	-0,15
2 - CaCO ₃ (1,0 Hg)	1,17	1,29	0,12
3 - NPK	1,28	1,35	0,07
5 - Manure (green manure) + CaCO ₃ (1,0 Hg)	1,47	1,53	0,06
6 - Manure (green manure + by-products) + NPK - Background	1,44	1,56	0,12
7 - Background + CaCO ₃ (1,0 Hg)	1,27	1,43	0,16
8 - Background + dolomite (1,0 Hg)	1,25	1,46	0,21
13 - 2 NPK + CaCO ₃ (1,0 Hg) + manure (green manure + by-products)	1,3	1,59	0,29
14 - 1,5 NPK + CaCO ₃ (1,5 Hg) + manure (green manure + by-products)	1,29	1,55	0,26
15 - 1,5 NPK + CaCO ₃ (1,0 Hg) + manure + by-products (green manure)	1,45	1,8	0,35
16 - BP - By-products + (green manure)	1,38	1,45	0,07
18 - 1,5 NPK + CaCO ₃ (1,0 Hg)	1,33	1,41	0,08
19 - 2 NPK + CaCO ₃ (1,0 Hg)	1,3	1,43	0,13

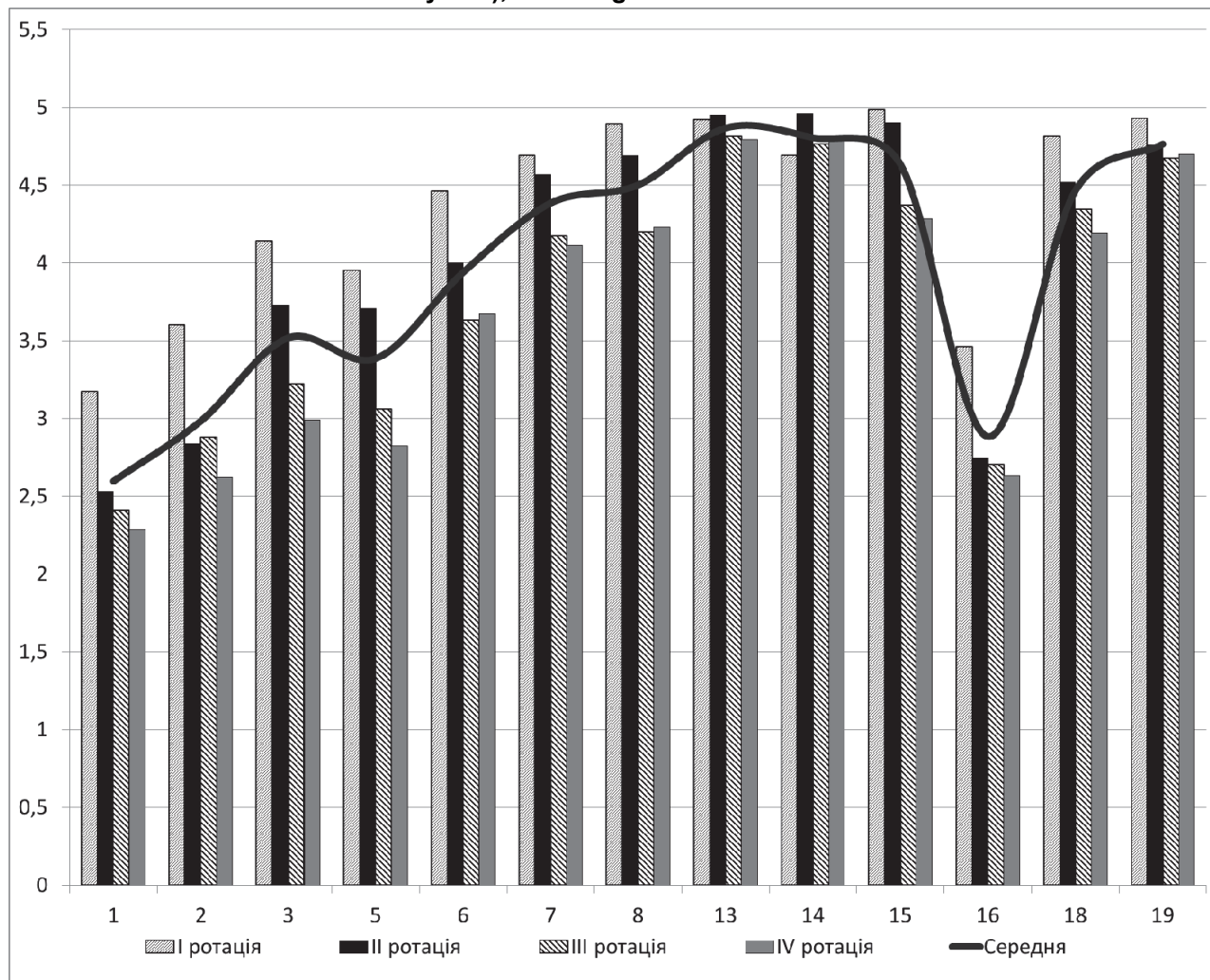
This suggests that liming positively affects the humus state of gray forest soil, both due to direct impact on crop yields and indirect, due to increased fertilizer use efficiency.

The largest accumulation of humus occurred in variants using organic fertilizers (manure, siderate, byproducts) in combination with moderate and elevated doses of mineral fertilizers against the background of liming with a full dose and half a dozen hydrolytic acidity. So the accumulation of humus for 24 years in these variants (var 13, 14, 15) was in the range from 21.75 to 23.08 t / ha.

Comparing the actual changes in the total content of humus during the years of research (Table 2) and the theoretical calculations of the humus balance in the soil layer of 0-20 cm for the prolonged use of different fertilizer and liming systems in crop rotation, it can be stated that the method of calculating the humus balance in the soil "Calculation of the balance of humus and nutrients in agriculture of Ukraine at different levels of management" confirms the correctness of our conclusions about the effect of liming under different fertilizer systems on the humus state of gray forest soil. The correlation coefficient between the actual and theoretically calculated humus balance is $R = 0,876$, indicating a close correlation between these figures, with the determination $D = 77\%$.

Data from our research (Figure 1) show that the productivity of crop rotation crops is closely related to the change in the humus state of gray forest soil. With the accumulation of organic matter in the soil, there is an increase in the productivity of crops. Thus, in the control version, without fertilizer application and application of chemical melioration, where there was a gradual decrease in humus content, there was a decrease in productivity from 3.17 t / ha of grain units in the first rotation of crop rotation, to 2.29 t / ha in IV rotation, and the average the productivity of agricultural crops for the investigated period amounted to 2.6 t / ha. The accumulation of humus content in variants using organic fertilizers in combination with moderate and elevated doses of mineral fertilizers against the background of liming with different doses of hydrolytic acidity (var 13-15) contributed to the increase in productivity of crops, which averaged from 4.63 to 4, 87 t / ha of grain units.

Figure 1. Productivity of crops depending on liming under different fertilizer systems (for 24 years), t / ha of grain units



In the process of mathematical analysis, a close correlation between the estimated humus balance and the average productivity of crops in crop rotation was established: the correlation coefficient is $R = 0.825$, and the determination $D = 68.1\%$.

Regression equation: $Y = 2,8637 + 0,1165X - 0,0016X^2$,

Where are: Y – average productivity of crops in crop rotation, t / ha of grain units;

X – Estimated humus balance for research period, t / ha.

With optimal points: $Y_{opt} = 4,98$ т/га з. о.; $X_{opt} = 36,4$ т/га.

Conclusions

The use of sour gray forest soils for growing crops without chemical melioration and the use of fertilizers leads to a decrease in the total content of humus from 1.34 to 1.19%, the humus balance for 24 years of use was scarce and amounted to 1.71 tons / ha, and the productivity of crops with each subsequent rotation decreased and averaged 2.6 t / ha of grain units.

Periodic calcination (once every 14 years) with a full dose of hydrolytic acid contributed to maintaining the content of total humus for growing crops, due to an increase in productivity of 15% compared to control and a humus balance was positive.

Increase of average productivity of crop rotation crops to 21.75-23.08 tons / ha of grain units on variants using organic fertilizers (manure, siderate, byproducts) in combination with moderate $N_{78}P_{42}K_{78}$ and increased $N_{108}P_{108}K_{112}$ doses of mineral fertilizers against the background of periodical liming complete and one and a half doses of hydrolytic acidity positively affects the flow of fresh organic matter, there is not only a direct relationship between the humus state and the harvest, but also the feedback, the high yield due to the increase in the mass of plant remains, remaining in the field, contributes to the predominance of processes of accumulation of organic matter over the processes of its mineralization. Thus, the average annual humus balance for organo-mineral fertilizer systems against the background of chemical melioration was from 0.91 to 0.96 t / ha.

Close correlation connections of the calculated balance of humus were established, as with the actual change in the content of total humus in the arable layer of gray forest soil for various fertilizing and liming systems - 0,876, and with the average productivity of crop rotation crops - 0,825, by determination, respectively, 77% and 68, 1%.

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