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THE IMPACT OF AGROCHEMICAL LOADING ON NUTRITIVE REGIME OF GRAY FOREST SOIL DURING FIELD CROP ROTATION

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ABSTRACT

This paper presents the results of studies on how mineral and organic fertilizers influence agrochemical indicators of gray forest coarse light loam soil. It was found that when applying the organo-mineral fertilizer systems ($N_{60}P_{60}K_{68}$ with 12 tons of manure per 1 ha of arable land) there was a tendency of increase of humus reserves to 35,1 t/ha per one treatment against the control of 28,1 t/ha. The application of 12 t/ha of manure in crop rotation under the organic fertilizer system contributed to the most intensive accumulation of humus reserves in the tilth top soil (0-20 cm) – 36,5 t/ha, with the soil solution acidity pH = 5,2. Over a five-year period, the average amount of hydrolyzable nitrogen in the experiment increased by 17-50%, mobile phosphorus compounds rose by 50-75 %, mobile potassium compounds increased by 27-50 % compared with the control of 44,1, 150 and 90,8 mg/kg of soil respectively. The highest level of fertility was provided by the application of $N_{60}P_{60}K_{68}$ with 12 tons of manure per 1 ha of crop rotation area, while the movement of nutrients took place within the root layer with no significant migration processes observed.

Key words: humus content, nitrogen, phosphorus, potassium, soil fertility, fertilizer system.

INTRODUCTION

Application of mineral and organic fertilizers improves agrochemical indicators of soil fertility (Vasbieva, 2019; Boyko et al., 2019; Degodyuk et al., 2020). However, the effectiveness of fertilizers' application, determined by the ratio of nutrients and their doses, largely depends on the abiotic conditions of the natural area. And the establishment of a balanced soil regime with intensive cultivation of crops on soils of light particle size distribution in the Ukrainian right-bank forest steppe requires additional study (Degodyuk et al., 2014; Litvinova et al., 2019; Symochko L., 2020; Dmitrenko O., 2021). Human economic activity, along with increasing the effective fertility of the soil, significantly affects the change of its potential fertility, creating over time artificial fertility, which corresponds to the category of natural economic (anthropogenic) fertility, which is identified as effective one (S. I. Veremeenko & O. A. Furmanets, 2014; Demyanyuk et al., 2020). Now the term 'normative fertility' is coming into

general use as the average long-term yield of certain crops grown under the adopted technology on a specific soil (Moskalenko, 2013). Depending on the intensity of land use for practical agriculture, the potential of soil fertility is important as a synthesis of natural and artificial soil fertility. It has the function of reproduction under the influence of human activity. H.A. Mazur (Mazur, 2008) emphasizes incomplete, simple and extended reproduction of soil fertility. All actions to increase the energy potential of the soil by applying organic and mineral fertilizers are the actions that facilitate an increase of the energy of potential soil fertility and increase yields and organic matter, which remains in the soil and contributes to the expanded reproduction of its fertility (Sirenko, 2012; Demyanyuk et al., 2019; Litvinov et al., 2019; Tanchyk et al., 2021). The goal of the work was to study the influence of the systematic use of fertilizers on the accumulation of nutrients in gray forest soils during the field crop rotation under different loads of mineral and organic fertilizers.

MATERIALS AND METHODS

The research was carried out during 2016-2018 in a stationary experiment of the Department of Agrochemistry at the experimental farm of NSC "Institute of Agriculture NAAS" on gray forest coarse light loam soil in a five-field crop rotation: grain maize, spring barley, buckwheat, pea, winter wheat. Physicochemical and agrochemical parameters were determined in the initial soil samples. The average sample of tilth top soil (0-20 cm) was characterized by the following agrochemical parameters: pH_{KCL} – 4,6 potentiometric; hydrolytic acidity – 1,61 mg-eq./100 g according to Kappen, the content of hydrolyzable nitrogen – 50,8 mg/kg of soil according to Cornfield; mobile phosphorus compounds – 120,0 mg / kg of soil, mobile potassium compounds – 100,0 mg/kg of soil according to Chirikov, organic matter content – 1,20% (according to Tyurin). We have studied the agronomic value of organic fertilizers — cattle manure without litter. It was found that the content of basic nutrients in 1 ton of manure was: N – 4,0 kg, P_2O_5 - 2,0 kg, K_2O – 4,0 kg.
The experiment was established in 2011 and took place in three fields; it included 11 options and four repetitions. The area under crops was 52 m^2, the accounting area was 22 m^2. The litter manure of cattle was applied to grain maize – a single dose of 60 t/ha, or in terms of 1 ha of crop rotation area - 12 t. The rest of the crops used the aftereffect - winter wheat in the 4-th year of the aftereffect. Varieties and hybrids of agricultural crops from the State Register of Plant Varieties of Ukraine were used in the study.
Soil samples were taken at the end of the first field rotation, every 20 cm. We determined: the content of organic matter (humus) - DSTU 4289: 2004; pH_{KCl} - (DSTU ISO 10390: 2001); hydrolyzable nitrogen content - according to Cornfield; the content of mobile compounds of phosphorus and potassium - in the gray forest soil - (DSTU 4115: 2002).

RESULTS

The influence of fertilizers on agrochemical indicators of soil fertility was studied during the field experiments on gray forest coarse loam light soil while cultivating the crops in a short-rotation field shift of crops. Due to the systematic application of fertilizers during one rotation, there was a tendency to change the nutrient regime in the root layer of the soil depending on the fertilizer system.

Systematic application of fertilizers in crop rotation has slightly increased the content of total humus in the soil. The results showed that in the tilth top soil (0–20 cm) there was a tendency of growing humus content to 1,15 % for the mineral fertilizer system, while the control content (without fertilizers) was 1,04 %. The humus content increased when we added organic matter of litter manure (1 time per rotation) at a dose of 60 t/ha: for moderate organo-mineral ($N_{60}P_{60}K_{68}$) - up to 1,30 % and organic - up to 1,35 % or in in terms of reserves in the 0-20 cm tilth top was 35,1 and 36,45 t/ha, respectively. The content of total humus under intertilled cultures and grain crops was less dependent on the type of vegetation and more dependent on the fertilizer system.

The results of research show that with the systematic conduct of a field experiment, the reaction of the soil solution on control without fertilizers was 5,1 units of pH_{salt}. During the period of first rotation the level of this indicator tended to be around $pH_{salt.}$ 5,2, with the use of organic fertilizer system, which corresponds to the gradation of

weakly acid reaction of soil solution and $pH_{salt.}$ 4,8 units for the use of mineral fertilizer system - medium acid (Table 2).

Table 1. Influence of agrochemical load on fertility indicators of gray forest soil in field experiment, tilth top soil (0-20 cm)

Fertilizers per 1 ha of crop rotation area		$pH_{salt.}$	Humus, %	Hydrolyzable nitrogen	Moving compounds	
manure, t	NPK, kg				phosphorus P_2O_5	potassium K_2O
				mg/kg		
Without fertilizers (control)		5,1	1,04	44,1	150,0	90,8
Organic fertilizer system						
12	–	5,2	1,35	57,0	235,5	115,5
Organic-mineral fertilizer system						
12	$N_{30}P_{30}K_{34}$	5,1	1,24	65,5	267,0	137,5
12	$N_{60}P_{60}K_{68}$	5,0	1,30	70,2	273,0	140,5
Mineral fertilizer system						
-	$N_{30}P_{30}K_{34}$	4,9	1,15	51,8	243,0	127,5
-	$N_{60}P_{60}K_{68}$	4,8	1,22	64,6	265,0	135,5
SSD_{05}		0,2	0,02	0,8	9,0	3,0

Nitrogen compounds in the soil belong to the most labile part of biogenic elements. Therefore, the application of nitrogen with fertilizers is mandatory every year, while phosphorus and potassium fertilizers are able to gradually accumulate when overused. The content of total nitrogen in the soil is determined by its compounds both in the mineralized part and in the organic matter that are accumulated in crop and root remains.

Systematic use of fertilizers in a 5-field field crop rotation is sufficient for the changes in the soil nitrogen reserve, which are consistent with the humus content of soil, as the organic compounds of the soil bind about 90 % of nitrogen. The quality of the soil organic matter influences the soil nitrogen transformation processes and the limits of its mobilization and use.

An important indicator of soil formation over time is the transformation of the immediate reserve of mineral nutrition of plants - hydrolyzable nitrogen. At the end of the 1st crop rotation, it was found that the equilibrium of its content shifted towards increasing the load of mineral fertilizers to 188 kg/ha NPK both separately and with the manure.

During long-term application of moderate doses of mineral fertilizers in crop rotation on gray forest soil, the content of hydrolyzable nitrogen in the tilth top soil (0–20 cm) was 64,6–70,2 mg/kg of soil, respectively. When using the organic fertilizer system, the nitrogen content was at the level of 57,1 mg/kg. In the variant without fertilizer application (control), its content was the lowest (44,1 mg/kg), because the nitrogen of these compounds was consumed by crops without replenishment of the nitrogen reserve from additional sources.

Thus, hydrolyzable nitrogen is a renewable value and compliance with its deficiency of up to 20 % is possible, because bringing its content to a higher level can be economically and environmentally costly.
In the subsoil layer (20–40 cm), the content of hydrolyzable nitrogen was practically equal to the control indicators without fertilizers (Fig. 1).

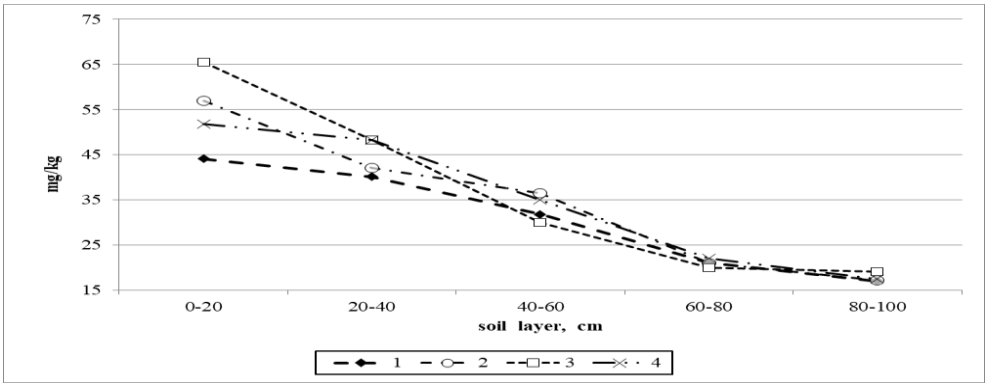

Figure 1. Influence of agrochemical loading on the accumulation of hydrolyzable nitrogen in gray forest soil (layer 0-100 cm) during field crop rotation, mg/kg

Fertilizers: 1 - Without fertilizers (control); 2 - 12 tons of manure per 1 ha of arable land; 3 - 12 tons of manure per 1 ha + $N_{30}P_{30}K_{34}$; 4– $N_{30}P_{30}K_{34}$.

The soil layer of 40–60 cm was characterized by the content of hydrolyzable nitrogen at the level of 30.0–40.0 mg/kg with a tendency to decrease in its deep horizons. Thus, in the process of mineral nutrition of the cult we did not reveal the migration processes of hydrolyzable nitrogen compounds. The analysis of the tilth top soil (0-20 cm) showed that during intensive crop rotation the content of mobile phosphorus increased to a maximum of 273,0 mg/kg of soil with organic-mineral fertilizer system (12 t/ha of manure+$N_{60}P_{60}K_{68}$), following moderate NPK loading (94 kg per 1 ha of crop rotation area) with organic-mineral - up to 267.0 mg/g of soil; for mineral fertilizer system with appropriate fertilizer - up to 265.0-243.0; and organic - 235.5 mg/kg of soil, which corresponds to a high level of supply of this element. The developed backgrounds on the accumulation of P_2O_5 can be a scientific basis for adjusting the phosphorus fertilizers loading during the crop rotation. In the soil layer of 40–60 cm while applying various fertilizers we observed a sharp decrease (by 2 times) of mobile phosphorus compared to the tilth top soil horizon. While in the layers of 60–80 cm there was a tendency to increase the phosphorus content within the root layer during the application of organic and mineral fertilizers with the concentration of up to 54,0-60,0 mg/kg of soil, and the control without fertilizers contained not more than 47,4 mg/kg. (Fig. 2).

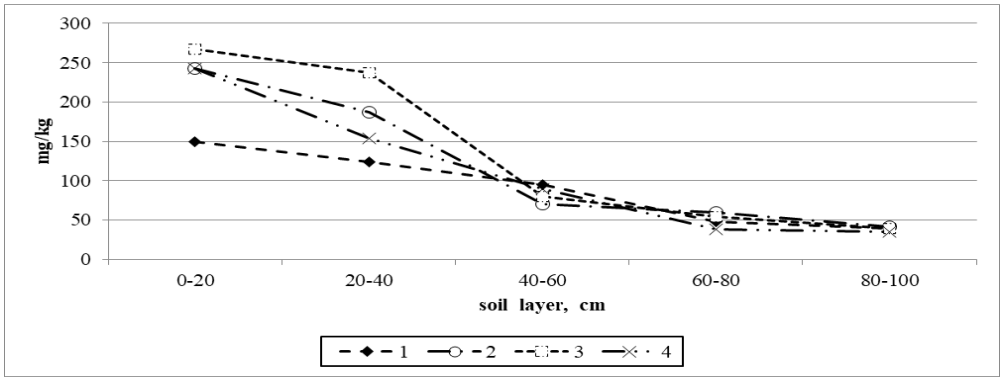

Figure 2. Influence of agrochemical loading on the accumulation of mobile phosphorus compounds in gray forest soil (layer 0-100 cm) during the field crop rotation, mg / kg

Fertilizer option: 1 - Without fertilizers (control); 2 - 12 tons of manure per 1 ha of arable land; 3 - 12 tons of manure per 1 ha of arable land + $N_{30}P_{30}K_{34}$; 4– $N_{30}P_{30}K_{34}$.

Phosphorus as an anion of phosphoric acid enters into chemical reactions in soil solutions and therefore it is characterized by a chemical type of absorption. This determines its specific nature, due to the fact that the phosphate reserve of the soil is able to gradually accumulate mobile and immobile phosphate compounds, the longer the cultivation of the soil takes place. The results of our experiment show that during the systematic application of

fertilizers, the content of mobile phosphorus compounds in the root layer of soils is gradually increasing. During the period of systematic application of fertilizers the optimal dose of fertilizers (12 t/ha of manure + $N_{66}P_{60}K_{68}$) the content of exchangeable potassium in the tilth top soil (0-20 cm) was 140,5 mg/kg, while the control without fertilizers contained 90,8 mg/kg of soil. At moderate doses of mineral fertilizers the content of exchangeable potassium was at the level of 135,5 mg/kg, which is 1.5 times higher than the control, and with the organic fertilizers there was an increase in exchangeable potassium by 27 % (Fig. 3). The results of research have shown that the accumulation of mobile potassium compounds in the soil is slower, which can be explained by its transition to non-exchangeable forms and removal of crops. With the content of K_2O equal to 90,0 mg/kg of soil in the control without fertilizers, we determined that its increase by 40,0 mg/kg of soil occurred after the introduction of moderate rates of fertilizers. In the deeper layers of 60–100 cm, the potassium content with the fertilizers' application gradually decreased comparing to the control (Fig. 3).

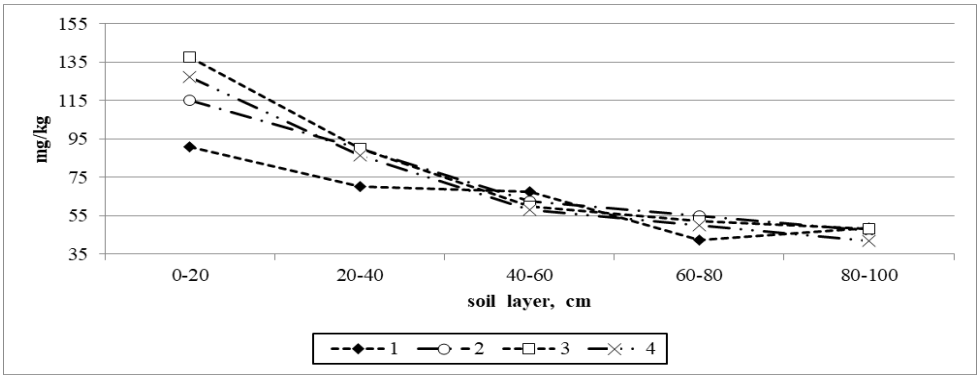

Figure 3. Influence of agrochemical loading on the accumulation of mobile potassium compounds in gray forest soil (layer 0-100 cm) during field crop rotation, mg/kg
Fertilizer option: 1 - Without fertilizers (control); 2 - 12 tons of manure per 1 ha of arable land; 3 - 12 tons of manure per 1 ha of arable land + $N_{30}P_{30}K_{34}$; 4 – $N_{30}P_{30}K_{34}$.

Thus, the content of hydrolyzable nitrogen in both the controls and the fertilized variants at the end of the rotation corresponded to the gradation of low supply, and the content of mobile phosphorus corresponded to the high supply gradation. With the systematic application of fertilizers there is a clear tendency to a slight increase (by 30-40 mg/kg of soil) in the content of mobile potassium, which compensates for its constant deficiency in the soil, on average, its content fluctuated between 120 and 140 mg/kg of soil, which corresponded to a high level of supply of this element.

CONCLUSIONS

- ✓ It was found that during the first rotation of the five-field crop rotation under the influence of organic fertilizers there was the formation of soil backgrounds with different physicochemical properties, the acidity of soil solution with organic fertilizers (12 t/ha of arable land) approached to $pH_{salt.}$ 5,2, while the mineral fertilizers brought the acidity closer to 4,2 pH units, which indicated the need for its recurrent liming.
- ✓ It was proved that there was a tendency to increase humus reserves to 35,1 t/ha in the tilth top soil (0-20 cm) when the soil was treated with $N_{60}P_{60}K_{68}$ accompanied with the background of 12 tons of manure per 1 ha of arable land against control – 28,1 t/ha.
- ✓ The application of 12 t/ha of manure in the crop rotation under the organic fertilizer system contributed to the most intensive accumulation of humus reserves in the tilth top soil 0-20 cm comprising 36,5 t/ha.
- ✓ We revealed that the mineral and organic fertilizers had a positive influence on the main agrochemical indicators of gray forest soil quality. Over a five-year period, the average amount of hydrolyzable nitrogen in the experiment increased by 17-50 %, mobile phosphorus compounds rose by 50-75 %, mobile potassium compounds increased by 27-50 %, compared with the control of 44,1, 150, 90,8 mg/kg of soil,

respectively. The highest level of fertility was provided by the application of $N_{60}P_{60}K_{68}$ against the background of 12 tons of manure per 1 ha of crop rotation area.

- ✓ One shift of a 5-field short-rotation crop rotation was not sufficient to create conditions for the accumulation of nutrients in the profile of gray forest coarse-grained light loam. The movement of nutrients took place within the root layer, no significant migration processes were observed.

REFERENCES

1. Boyko P., Litvinov D., Demidenko O., Blashchuk M., Rasevich V. (2019) Prediction humus level of black soils of forest-steppe Ukraine depending on the application of crop rotation, fertilization and tillage International Journal of Ecosystems and Ecology Science (IJEES) Vol. 9 (1): 155-162 DOI: 10.31407/ijees9118 (ISSN: 2224-4980);
2. D. V. Litvinov, A. O. Butenko, V. I. Onychko, T. O. Onychko, L. V. Malynka, I.M. Masyk, L.M. Bondarieva, O. L. Ihnatieva (2019) Parameters of biological circulation of phytomass and nutritional elements in crop rotations. Ukrainian Journal of Ecology, 9(3), 92-98. https://doi.org 10.15421/2019_714;
3. Degodyuk, S. E., Litvinova, O. A., Smishna-Starynska, L. V. (2014). Vplyv dovhotryvaloho zastosuvannya orhano-mineral′noyi systemy udobrennya na humusnyy stan siroho lisovoho gruntu i produktyvnosti kul′tur [Influence of long-term application of organo-mineral fertilizer system on humus condition of gray forest soil and crop productivity]. Collection of scientific works of Podolsk State Agrarian Technical University. 59-65;
4. Olena Demyanyuk, Lyudmyla Symochko, Hosam E.A.F. Bayoumi Hamuda, Vitaliy Symochko, Olga Dmitrenko (2019) Carbon pool and biological activities of soils in different ecosystems. International Journal of Ecosystems and Ecology Sciences (IJEES) 9 (1), p. 183-188;
5. Olena Litvinova, Dmytro Litvinov, Svitlana Romanova, Svitlana Kovalyova (2019) Soil biological activity under the human-induced impact in the farmed ecosystem. International Journal of Ecosystems and Ecology Science (IJEES) Vol. 9 (3): 529-536 DOI: https://doi.org/10.31407/ijees9316 ISSN: 2224-4980;
6. S. I. Veremeenko & O. A. Furmanets (2014). Changes in the agrochemical properties of dark gray soil in the Western Ukrainian forest-steppe under the effect of long-term agricultural use. Eurasian Soil Science volume 47, pages 483–490. doi:10.1134/S106422931405024X;
7. S. Tanchyk, D. Litvinov, A. Butenko, O. Litvinova, O. Pavlov, A. Babenko, N. Shpyrka, V. Onychko, I. Masyk and T. Onychko (2021) Fixed nitrogen in agriculture and its role in agrocenoses. Agronomy Research 19(2), 601–611 https://doi.org/10.15159/AR.21.086;
8. Vasbieva, M.T. Effect of Long-Term Application of Organic and Mineral Fertilizers on the Organic Carbon Content and Nitrogen Regime of Soddy-Podzolic Soil. Eurasian Soil Sc. 52, 1422–1428 (2019). https://doi.org/10.1134/S1064229319110139;
9. Dmitrenko O., Tkachenko M., Pavlichenko A. (2021). Changes in the nitrogen regime of gray forest coarse-dusty-loamy soil under different systems of fertilizers and chemical reclamation. Plant and soil science vol. 12, №1, 77-85 doi.org10.31548/agr2021.01.077;
10. Mazur GA (2008) Reproduction and regulation of light soil fertility. K .: Agrarian Science, 308 p;
11. Moskalenko AM (2013) Biological and economic factors of expanded reproduction of soil fertility in Polissya. Organic production and food security. Zhytomyr: Polissya, pp. 83–92;
12. Sirenko N., Chaika T. (2012). Organic food in ensuring food security of Ukraine. Economics of agro-industrial complex. № 1. pp. 43-49;
13. Symochko L. Soil microbiome: diversity, activity, functional and structural successions. International Journal of Ecosystems and Ecology Sciences. 2020. 10(2). P. 277–284. https://doi.org/10.31407/ijees10.206;
14. Demyanyuk O., Symochko L., Mostoviak I.I. Soil microbial diversity and activity in different climatic zones of Ukraine. Regulatory Mechanisms in Biosystems. 2020. 11(2). P. 338-343. https://doi.org/10.15421/022051;
15. Degodyuk SE, Degodyuk EG, Litvinova OA etc. (2020) Change in agrophysical indicators of gray forest soil with long-term use of organic and mineral fertilizers. Bulletin of Agricultural Science. № 1., pp.19-24. (https://doi.org/10.31073/agrovisnyk202001-03);