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Humus state and nutrient regime of typical chernozem depending on fertilisation in short crop rotations

Abstract. The fertiliser system is the most effective factor in the intensification of crop cultivation technologies. The basis for scientifically sound fertiliser application systems, along with obtaining the planned level of yield of the appropriate quality, is the study of the organic matter content and soil nutrient regime during crop rotation. The purpose of this study was to determine the mineral nitrogen, mobile phosphorus, exchangeable potassium, and humus content in typical chernozem

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under different fertilisation systems in short-term crop rotations. To solve the problem of soil fertility, an important approach is to conduct field and laboratory research to determine changes in the humus state according to Tyurin, nitrogen, phosphorus, and potassium regimes of the soil according to Machigin, and dispersion methods to determine the reliability of experimental data. As a result of the research, it was found that the highest humus content in the soil was recorded under the organic-mineral fertilisation system at the end of the second rotation in the grain crop rotation by 0.13% compared to the fruit crop rotation. The use of a mineral fertiliser system in a row crop rotation reduced the humus content by 0.12%. An increase in the humus content of typical chernozem was recorded under fruit crop rotation and grain-row crop rotation. The organic-mineral fertilisation system tended to increase the mineral nitrogen content of the soil compared to the other systems. The mineral nitrogen content of the mineral fertilisation system decreased by 5.5 mg/kg of soil compared to the unfertilised variant. Under the organic-mineral and mineral fertilisation system, the content of mobile phosphate increased in all crop rotations. The content of mobile phosphorus in the tilled crop rotation was substantially reduced compared to the fruit crop rotation and grain-row crop rotation. The highest content of exchangeable potassium in the soil was recorded under the mineral fertilisation system. The materials of the publications are of practical importance in the analysis of the main elements of mineral nutrition of typical chernozem in short crop rotations

Keywords: mineral nitrogen; exchangeable potassium; sunflower; nutrients, agrocenosis

INTRODUCTION

As of 2023, under lease relations, soils are a source and means of profit. Agricultural landowners ignore the fact that without efforts to restore land fertility, significant resources will need to be spent today and, in the future, to achieve the original level of fertility. Analysing the changes in the quality of Ukraine's soils in recent years, there is a dangerous trend towards a decline in their fertility and deterioration of the environmental situation, which will lead to a crisis in agriculture. According to the National Research Centre "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine", up to 20 million tonnes of humus are lost in Ukraine every year, which is 600-700 kg per 1 hectare of arable land. Other measures to restore soil fertility are needed to change the situation. It is necessary to optimise the organic matter regime and prevent the loss of humus and humus status of soils (Egorov *et al*., 2021).

The intensification of agricultural production technologies since 2010 has substantially exacerbated the problem of soil degradation (Grzebisz *et al*., 2022). According to I.M. Uzoh *et al*. (2019), optimisation of the fertilisation system and crop rotation structure are the simplest and most effective agronomic measures to achieve sustainable production and restore natural soil fertility. In Ukraine, there is currently a shortage of manure in agriculture and a significant decrease in the share of perennial legumes in crop rotations (Ivanina & Korotenko, 2023). According to M.A. Bolinder *et al*. (2020), R. Allende-Montalban *et al*. (2022), the countries of the European Union and the United States are developing the agricultural sector on the widespread use of biological nitrogen in crop rotation fertilisation, reducing carbon emissions in the soil. These measures significantly reduce the cost of nitrogen fertilisers, contribute to soil moisture conservation, improve soil structure, and enhance humus formation (Hossain *et al*., 2022). In the context of global warming, this practice helps to stabilise plant mineral nutrition and moisture supply, enhances their resistance to adverse weather conditions, and makes modern technologies more sustainable.

According to N.E. Borys & L.M. Krasyuk (2020), provided that chernozems have high agrophysical properties, it should be assumed that the content of total humus reaches its optimum. The importance of organic matter as a source of nitrogen for plants should be considered when determining the optimal humus content (Ting-ting *et al*., 2022). O.A. Tsyuk *et al*. (2022) noted that the humus content in the soil will be optimal when nitrogen nutrition of crops, along with agrophysical properties, does not limit the productivity of crops in crop rotations. For typical chernozems, the humus content is 4.0-6.5% (Hospodarenko *et al*., 2019).

The use of fertiliser systems for sunflower in short crop rotations is particularly relevant to preserve soil fertility. The issue of improving soil nutrition of plants by using different fertiliser systems, different agronomic practices and changing agrochemical parameters in short crop rotations is relevant. The purpose of this study was to determine changes in the humus state and specific features of the formation of nitrogen, phosphorus, and potassium regime of typical chernozem under different fertilisation systems in short crop rotations.

MATERIALS AND METHODS

The study was conducted in 2012-2021 in a stationary experiment of the Bila Tserkva National Agrarian University on typical black soil. The soil of the experimental plot is a typical deep low-humus black soil with the following physicochemical and agrochemical characteristics of the 0-30 cm layer: hydrolysed nitrogen – 110 mg/kg of soil; mobile phosphorus and exchangeable potassium – 120-110 mg/kg of soil, respectively; humus content according to Tyurin – 3.7-3.9%; salt pH – 6.0-6.4; Ng according to Kappen – 1.09-1.26 mg-eq/100 g of soil; the sum of absorbed bases according to Kappen-Hilkowitz – 23.8-27.2 mg-eq/100 g of soil; soil density within 1.16-1.25 g/cm^3, and the total porosity is 52-55%. The repetition of the experiment was threefold. The repetition was placed on the area (territory) in a continuous, systematic manner, with fertiliser variants placed in four tiers sequentially. The area of the elementary plots: 171 m^2, the accounting area – 112m^2.

The study was conducted in the agrocenosis of sunflower, which was grown after winter wheat in four five-field short crop rotations: fruit crop rotation (sunflower saturation of 10%) – alfalfa – winter wheat – sugar beet, sunflower – buckwheat – barley + alfalfa; grain-row crop rotation (sunflower saturation of 20%) – soybeans – winter wheat – sunflower – spring barley – maize; specialised grain-row crop rotation (30% sunflower content) – buckwheat – winter wheat – maize, sunflower – barley – sunflower; row crop rotation (40% sunflower content) – peas – winter wheat – sunflower – maize – sunflower.

Content of fertiliser system gradations. Zero level – no fertiliser. Organic – application of 8 tonnes and 3.0 tonnes of non-marketable part of the crop, mass of green manure per hectare of crop rotation area. The organic fertiliser rate was determined according to the need for a positive humus balance. Organo-mineral – priority use of organic fertilizers to restore soil fertility, application of 8 tonnes of manure per 1 ha of crop rotation area and 3.5 tonnes of siderable crop mass, by-products, application of 110 kg ($N_{27}P_{38}K_{45}$) of mineral fertilizers. Mineral – application of 8 tonnes of manure and 222 kg ($N_{68}P_{72}K_{82}$) of mineral fertilizers per 1 ha of crop rotation area. Semi-rotted manure, ammonium nitrate, simple granular superphosphate, and potassium salt were applied.

In all variants, the remaining wheat straw was chopped after harvesting and incorporated into the soil with a disc harrow. After harvesting wheat, the soil was prepared for sowing white mustard on green manure. In late September and early October, post-harvest mustard crops were ploughed into the soil in all variants. Manure was applied at a rate of 40 t/ha.

Soil samples were collected in 0-25 cm layers at five points of each experimental plot. In a weighted average soil sample, the content of humus was determined according to Tyurin (DSTU 4289:2004..., 2004); nitrogen of mineral compounds (DSTU 4729:2007..., 2007); mobile phosphorus and potassium compounds – according to Machigin (DSTU 4114-2002..., 2002). The results of the study were statistically calculated using the method of analysis of variance and correlation. The study was conducted per the requirements of the International Convention on Biological Diversity (1992).

RESULTS

The results of the study showed that the humus content in chernozem, a typical sunflower agrocenosis in the 0-25 cm soil layer in short crop rotations, depended on the fertilisation system. Thus, in a grain-row specialised crop rotation with 30% sunflower saturation under the organic fertilisation system, the humus content increased by 0.10% in the tillage layer in a fruit crop rotation by 0.13% (Table 1). In the grain-row crop rotation, the humus content had a smaller increase compared to the fruit crop rotation.

Table 1. Changes in humus content in typical chernozem depending on crop rotation and fertilisation system, %, (2012-2021)

Crop rotation	Fertilizer system	Start of the first rotation	End of the second rotation	+/- to control
Fruit crop rotation	Without fertilisers (St)	3.83	3.58	-0.25
	Organic	3.87	3.99	+0.12
	Organic-mineral	3.89	4.06	+0.17
	Mineral	3.87	3.85	-0.02
Grain-row crop rotation	Without fertilisers (St)	3.91	3.77	-0.14
	Organic	4.02	4.18	+0.16
	Organic-mineral	3.96	4.19	+0.23
	Mineral	3.91	3.83	-0.08
Specialised grain-row crop rotation	Without fertilisers (St)	3.92	3.82	-0.10
	Organic	3.94	4.04	+0.10
	Organic-mineral	3.87	4.00	+0.13
	Mineral	3.81	3.72	-0.09
Row crop rotation	Without fertilisers (St)	3.80	3.70	-0.10
	Organic	3.86	3.96	+0.10
	Organic-mineral	3.85	3.93	+0.08
	Mineral	3.82	3.70	-0.12
LSD_{05}		0.14	0.22	

Source: compiled by the authors of this study

This is conditioned upon the fact that the synthesis of organic matter was somewhat slowed down by mineralisation, which was more intense under row crops as opposed to perennial grasses and cereals. In a grain-row crop rotation with 20% sunflower saturation, under the organic-mineral and organic fertilisation system, the humus content increased by 0.23% and 0.16% in the tilled soil layer at the beginning and end of the growing season, respectively, compared to the fruit crop rotation. The small increase in humus is explained by the fact that soybeans were sown in the crop rotation, followed by winter wheat, and as a result, the biological nitrogen that entered the soil as a result of nitrogen fixation was almost completely used by crops in the rotation and its replenishment in the soil was insignificant, which affected the humus content.

Under the organic-mineral fertilisation system in a row crop rotation, the amount of humus increased by 0.08% over two rotations. Thus, the organic-mineral fertilisation system stabilises and increases the humus content in crop rotations. The greatest increase in humus content was observed in fruit crop rotation and grain-row crop rotation. Under the mineral fertilisation system, the humus content decreased in all the crop rotations under study. In a rotational crop rotation with a mineral fertilisation system, the humus content decreased, and its losses reached 0.02%. In the grain-crop rotation, the humus losses under this fertilisation system were slightly higher than 0.08%. In the specialised grain-row crop rotation, the application of the fertilizer rate $N_{87}P_{75}K_{83}$ during the crop rotation period increased the mineralization of organic matter according to the norm of the organo-mineral fertilization system, 0.09% of humus was lost.

Application of a high rate of fertilisers $N_{68}P_{82}K_{84}$ for the row crop rotation decreased the content of humus and its losses reached 0.12%. The loss of humus in the lower layers of the soil in a row crop rotation is explained by the fact that cultivation and saturation with row crops create conditions for the mineralisation of organic matter throughout the root layer of the soil. This is also facilitated by hydrothermal conditions in autumn, winter, and spring, when microbiological processes continue to operate throughout the soil profile.

With the organic-mineral fertilisation system, the humus content in all crop rotations increased due to an increase in the amount of non-hydrolysed residue. The highest humus content was observed in fruit crop rotation and grain-row crop rotation, and less in specialised grain-row crop rotation. The soil nutritional regime was analysed according to the content of nutrients in the soil in the phase of full ripeness of sunflower. Nitrogen is essential, especially in plants, and in soil it is one of the main and key elements for the growth and development of crops. Dynamic mineral nitrogen that changes during the growing season due to the activity of biological processes and the use of nitrogen by plants during the growing season to form crop yields. The productivity of the crop and the quality of the product depends on the availability of mineral nitrogen.

It was noted that under the organic fertilisation system, the amount of mineral nitrogen did not significantly increase in the fruit crop rotation by 1.4 mg/kg of soil, and in the grain-row crop rotation by 1.6 mg/kg of soil compared to the organic-mineral system, but the specialised grain-row crop rotation and the row crop rotation tended to slightly reduce the content of mineral nitrogen in the soil compared to the organic-mineral system (Table 2).

Table 2. Mineral nitrogen content in typical chernozem depending on the fertilisation system in short crop rotations, mg/kg soil (2013-2016)

Fertilizer system	Crop rotation			
	fruit crop rotation	grain-row crop rotation	specialised grain-row crop rotation	row crop rotation
Without fertilisers	13.8	16.8	15.4	12.9
Organic	20.3	21.0	18.2	17.6
Organic-mineral	18.9	19.4	18.8	18.0
Mineral	19.0	18.3	18.1	16.8
LSD_{05}	1.7	2.0	1.6	1.1

Source: compiled by the authors of this study

In the mineral fertilisation system variant, the mineral nitrogen content decreased significantly in the grain-row crop rotation – by 2.7 mg/kg of soil compared to the organic system, due to the use of sunflower nitrogen, the development of nitrifying microorganisms and the course of sunflower mineralisation processes. The organo-mineral fertilisation system contributed to a substantial increase in the mineral nitrogen content of the specialised grain-row crop rotation and row crop rotation. The fertilisation system influenced the content of mobile phosphorus and exchangeable potassium. Under row crop rotation, the content of mobile phosphorus in the organic fertilisation system decreased by 7.4 mg/kg of soil compared to the organic-mineral system (Table 3).

Table 3. The content of mobile phosphorus in typical chernozem in sunflower agrocenosis depending on the fertilisation system in short crop rotations, mg/kg, soil

Fertilizer system	Crop rotation			
	fruit crop rotation	Grain-row crop rotation	specialised grain-row crop rotation	row crop rotation
Without fertilisers	16.9	13.0	13.9	16.4
Organic	21.7	21.2	21.0	18.8

Table 3, Continued

Fertilizer system	Crop rotation			
	fruit crop rotation	Grain-row crop rotation	specialised grain-row crop rotation	row crop rotation
Organic-mineral	28.9	29.6	27.6	26.2
Mineral	32.6	31.4	28.6	27.4
LSD_{05}	5.4	3.9	4.0	4.9

Source: compiled by the authors of this study

In fruit crop rotation and grain-row crop rotation, both with mineral and organo-mineral fertiliser backgrounds, the phosphorus content did not decrease due to less phosphorus use by plants. These variants tend to increase phosphate mobility across all crop rotations. In a row crop rotation, there is a substantial decrease in the content of mobile phosphorus in the cultivated soil layer compared to other crop rotations. This is conditioned upon the use of phosphorus by sunflower, which occupies 40% of the crop rotation area in row crop rotation, and, on the other hand, due to a decrease in the microbiological activity of black soil and its nitrification capacity, which results in less phosphate being transferred to the mobile state. The distribution of exchangeable potassium in the root layer of the soil is presented in Table 4.

Table 4. Availability of exchangeable potassium in the soil in sunflower agrocenosis depending on the fertilisation system in short crop rotations, mg/kg of soil (2013-2016)

Fertilizer system	Crop rotation			
	fruit crop rotation	grain-row crop rotation	specialised grain-row crop rotation	row crop rotation
Without fertilisers	109.0	111.4	107.0	108.0
Organic	117.0	114.0	111.0	108.0
Organic-mineral	129.0	131.0	125.0	120.0
Mineral	150.0	205.0	139.0	157.0
LSD_{05}	13.0	14.0	5.4	5.6

Source: developed by the author of this study

The organo-mineral fertilisation system considerably reduced the exchangeable potassium content compared to the mineral system, due to a decrease in soil potassium fixation and the release of non-exchangeable potassium into mobile exchangeable compounds. The organic fertilisation system did not achieve the optimum exchangeable potassium content for sunflower cultivation in typical black soil. Its level in the treated layer gradually decreased. When applying mineral fertilisers in the variants of the mineral and organo-mineral fertilisation system, a decrease in the proportion of easily soluble forms of potassium was found relative to mobile forms.

This is because the potassium in mineral fertilisers is in a highly soluble form and is quickly taken up by plants, resulting in increased crop yields and potassium removal. However, this dosage is insufficient to enhance the level of readily soluble potassium in the soil. The potassium contained in manure is part of organic matter, which is more difficult to transfer to the soil solution, and therefore plants in such conditions use other forms of potassium compounds in chernozem (Nikitina & Vasylenko, 2019). The authors' research revealed an insignificant, average relationship between the content of mineral nitrogen in the 0-25 cm layer and sunflower yield ($r = 0.41 \pm 0.24$), but a significant strong relationship was established between the content of mobile phosphorus in the 0-25 cm layer and sunflower yield ($r = 0.87 \pm 0.13$), exchangeable potassium and sunflower yield ($r = 0.72 \pm 0.18$).

DISCUSSION

In different years, scientists have conducted comparable studies on similar topics. Under the influence of the application of 7.5 t/ha of manure + $N_{50}P_{66}K_{66}$ in grain-row crop rotation in leached chernozems, the humus content increased by 0.13% (Pinkovskyi *et al.*, 2019). In works on chernozems in a soil-protective crop rotation, the humus content in the arable layer increased by 0.26% and 0.46% in the subsoil layer from the application of 7.5 t/ha of manure + $N_{70}P_{70}K_{35}$.

Some scientists believe that the annual loss of humus due to mineralisation in fruit crop rotation and green manure crop rotation is 1.32 t/ha (Tsyuk *et al.*, 2018). Thanks to plant residues, the loss of humus is compensated for, the rest must be compensated for by applying organic fertilisers (manure, green manure, straw). During humification, from 0.62 to 0.87 t/ha of humus can be produced from plant residues in a fruit crop rotation, depending on crop yields. Green manure crop rotation allows for an additional supply of 1.01 to 1.19 tonnes of humus per hectare. According to scientists, 40 tonnes of manure per hectare applied to potatoes and maize can produce 0.42 tonnes of humus. With 1 t of straw per hectare of the crop rotation area, the humus content increases by 0.15 t/ha.

Typical deep low-humus chernozems have a high absorption complex with a significant proportion of alkaline earth bases, which are characterised by an increase in humus substances, the amount of which depends on the organic-mineral fertiliser system, specific features of crop rotation, and soil cultivation. The humus content in a zone of sufficient moisture depends on both the fertilisation system and the presence of perennial grasses and legumes in the crop rotation.

In the crop rotation without legumes, humus losses were slightly higher, due to a lower stock of biological nitrogen in the soil, increased mineralisation of organic matter, and humus losses in the tilth and subsoil layers reached 0.35% and 0.32% (Plisko & Kutsova, 2023). The research by V.P. Boyko (2020), conducted at the Uladova-Lyulynetska Experimental Breeding Station, showed that the system of fertilisation of crops and their rotation in crop rotation affects the humus content. In a crop rotation without legumes, humus losses over 10 years in the tilth layer reached 0.27% and in the fallow layer 0.22%. The study by N.E. Borys & L.M. Krasyuk (2020), conducted at the Verkhnyatsk Experimental Breeding Station on podzolic heavy loam chernozems, observed stabilisation of organic matter, with an upward trend in its initial content. The authors explain this by suggesting that the amount of organic matter left by the crops in the rotation was sufficient to maintain a positive humus balance.

Research conducted by O. Kachmar *et al.* (2020) in the conditions of the Carpathian region shows that the combined application of mineral fertilizers $N_{120}R_{100}K_{100}$ for maize and $N_{90}R_{90}K_{90}$ for potatoes on a background of manure (40 t/ha) contributed to obtaining 568.36 mg/100 g and 537.61 mg/100 g, and 22.74 mg/100 g and 21.87 mg/100 g of soil of labile and water-soluble humus, respectively, in grain and fruit crop rotations. The use of an alternative fertilisation system ensured their values at the level of 482.15-470.84 mg/100 g of soil and 19.47-20.21 mg/100 g of soil.

In July, in the middle of the sunflower growing season, the content of mineral nitrogen in the surface and subsurface soil layers decreased significantly, due to the fact that sunflower plants use it and mineral nitrogen compounds migrate to the lower soil layers. Depending on the experimental variants, 70% of the total amount of mineral nitrogen was ammonium nitrogen, which is explained by the use of sunflower nitrates and an increase in the proportion of immobilised nitrogen, which is immobilised in the form of NH_4 (Boyko, 2020).

According to Egorov *et al.* (2021), if the phosphorus uptake from fertiliser phosphate application on all backgrounds is levelled out by day 130-150, the difference in phosphorus mobility persists until the end of the period. When a certain level of phosphorus saturation is reached, the soil acquires the ability to quickly restore the balance of soluble phosphates in the soil solution, i.e., it is characterised by greater capacity to meet the phosphate nutrition needs of plants. The supply of mobile phosphorus to sunflower agrocenosis is largely related to the seasonal dynamics of this nutrient (da Silva *et al.*, 2023), which depends on humidity and temperature (Tsentilo *et al.*, 2018).

In the research of S. Martyniuk *et al*. (2019), the consumption of phosphate fertilisers increased from 34 to 123 kg/ha on different soil types to increase the level of mobile phosphorus by 7 mg/kg of soil. To increase the content of mobile phosphate by 1 mg/kg of soil on chernozem soils, S.M. Kramarev *et al*. (2015) recommended applying phosphate fertilisers at rates of 40-60 kg, which exceeded the removal of this element and largely depended on the soil type and the level of phosphorus supply. The highest rates of nitrogen accumulation were observed in fruit crop rotation (+48.4 kg/ha) and grain-row crop rotation (+39.6-44.9 kg/ha) under the conventional fertilisation system. The lowest values of nitrogen balance (+28.9-33.1 kg/ha) were in grain crop rotations. A positive phosphorus balance was achieved by all fertilisation systems used in all crop rotations under study. The highest values of this indicator were obtained on conventional organic-mineral backgrounds of grain-row (+65.4-67.8 kg/ha) crop rotations. It was somewhat lower in the grain (+52.0 kg/ha), fruit (+45.0 kg/ha) and fodder (+44.3 kg/ha) crop rotations.

In other words, research on different soil types strongly suggests that the application of phosphate fertilisers to various crops can considerably affect phosphorus mobility and accumulation. The results of these studies suggest that the best rates of phosphate fertiliser application depend on the type of soil and crop requirements in the crop rotation system.

CONCLUSIONS

The humus content of the soil was determined by the application of mineral and organic fertilisers and did not significantly depend on crop rotation. The maximum humus content in the soil was reached by 0.13% higher at the end of the second rotation in the grain-row crop rotation compared to the fruit crop rotation when using the organic-mineral fertilizer system. With the organic-mineral fertilisation system, the humus content in all crop rotations increased due to an increase in the amount of non-hydrolysed residue. The highest humus content was observed in fruit and grain-row crop rotations, and the lowest – in specialised grain-row crop rotation. In the unfertilised variants, due to the growing mineralisation, the largest losses were in the specialised grain-row crop rotation.

The mineral nitrogen content of sunflower in short crop rotations was sufficient to obtain a sufficient level of yield. Under the mineral fertilisation system, the mineral nitrogen content decreased, due to the suppression of nitrification processes in the typical chernozem typical of the right-bank Forest-Steppe of Ukraine. The organic-mineral fertiliser system had an advantage in terms of its content in the soil compared to the mineral system. The organic fertilisation system had a slight tendency to increase the nitrogen content of mineral soils compared to the mineral one. The content of mineral nitrogen in the soil decreased significantly under the row crop rotation and specialised grain-row crop rotation.

The use of mineral and organo-mineral fertilisation systems in crop rotations contributes to a greater use of mobile phosphorus by crops in short crop rotations and the formation of high phosphate content in black soil. An increased content of mobile phosphorus was observed in fruit and grain-row crop rotation. Row crop rotation led to a decrease in the content of mobile phosphorus in typical chernozem. The migration of exchangeable potassium on typical chernozems depended on the system of fertilisation of crops in the crop rotation. The highest content of exchangeable potassium was observed in the fruit crop rotation under the mineral fertilisation system. A promising area for further research is the study of the fractional composition of humus and phosphate migration in the one-metre soil thickness under fruit and grain-row short crop rotation.

Extensive agrochemical analysis of the soil can provide detailed scientific information. Comparative analysis of research results in field stationary experiments is important. To establish the specific features of changes in indicators characterising soil fertility, the state and characteristics of microbiological processes, physical and chemical properties, and the intensity of soil load under diverse fertilisation systems, research institutions are recommended to conduct more in-depth studies that will cover these issues and establish the most suitable combination of regulated factors in the soil-plant-productivity system.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Allende-Montalban, R., Martin-Lammerding, D., del Mar Delgado, M., Porcel, M.A., & Gabriel, J.L. (2022). Nitrate leaching in maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) srrigated cropping systems under nitrification inhibitor and/or intercropping effects. *Agriculture*, 12(4), article number 478. doi: 10.3390/agriculture12040478.

[2] Bolinder, M.A., Crotty, F., Elsen, A., Frac, M., Kismanyoky, T., Lipiec, J., Tits, M., Toth, Z., & Katterer, T. (2020). The effect of crop residues, cover crops, manures and nitrogen fertilization on soil organic carbon changes in agroecosystems: A synthesis of reviews. *Mitigation and Adaption Strategies for Global Change*, 25, 929-952. doi: 10.1007/s11027-020-09916-3.

[3] Borys, N.E., & Krasyuk, L.M. (2020). Nutrient regime of gray forest soil under different anthropogenic load. *Collection of Scientific Works "Agrobiology"*, 2, 16-26. doi: 10.33245/2310-9270-2020-161-2-16-26.

[4] Boyko, V.P. (2020). *Effectiveness of doses and ratios of mineral fertilizers in field crop rotation on podzolized chernozem of the Right Bank Forest Steppe of Ukraine* (Doctoral dissertation, Uman National University of Horticulture, Uman, Ukraine).

[5] Convention on Biological Diversity. (1992). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[6] da Silva, L.I, Pereira, M.C., de Carvalho, M.X., Buttros, V.H., Pasqual, M., & Doria, J. (2023). Phosphorus – solubilizing microorganisms: A key to sustainable agriculture. *Agriculture*, 13(2), article number 462. doi: 10.3390/agriculture13020462.

[7] DSTU 4114-2002. (2002). *Soils. Determination of mobile phosphorus and potassium compounds by the modified Machigin method*. Retrieved from http://online.budstandart.com/ua/catalog/doc-page?id_doc=58928.

[8] DSTU 4289:2004. (2004). *Soil quality. Methods for determination of organic matter*. Retrieved from http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=56400.

[9] DSTU 4729:2007. (2007). *Soil quality. Determination of nitrate and ammonium nitrogen in the modification of the Sokolovsky NSC IGA*. Retrieved from http://online.budstandart.com/ua/catalog/doc-page?id_doc=72836.

[10] Egorov, O.V., Zhidok, N.P., Gryshchenko, O.M., & Shabanova, I.I. (2021). The effect of fertilizers on the fertility indicators of sod-podzolic soils and the productivity of short-rotational crop rotations in Polissia. *Agroecological Journal*, 3, 119-126. doi: 10.33730/2077-4893.3.2021.240329.

[11] Grzebisz, W., Diatta, J., Barlog, P., Biber, M., Potarzycki, J., Lukowiak, R., Przygocka-Cyna, K., & Szczepaniak, W. (2022). Soil fertility clock - crop rotation as a paradigm in nitrogen fertilizer productivity control. *Plant (Basel)*, 11(21), article number 2841. doi: 10.3390/plants11212841.

[12] Hospodarenko, G., Cherno, O., & Cherednik, A. (2019). Formation of soil fertility for different fertilizer systems in field crop rotation. *Agrology*, 2(2), 79-85. doi: 10.32819/019011.

[13] Hossain, M.L., Li, J., Hoffmann, S., & Beierkuhnlein, C. (2022). Biodiversity showed positive effects on resistance but mixed effects on resilience to climatic extremes in a long-term grassland experiment. *Science of the Total Environment*, 827, article number 154322. doi: 10.1016/j.scitotenv.2022.154322.

[14] Ivanina, V.V., & Korotenko, I.M. (2023). State of humus and nutrient regime of leached chernozem depending on fertilizer and crop rotation link. *The Latest Agricultural Technologies*, 11(1). doi: 10.47414/na.11.1.2023.277356.

[15] Kachmar, O., Vavrynovych, O., Dubytskyi, O., Dubytska, A., Shcherba, M., & Vovk, A. (2020). Scientifically substantiated short crop rotations in the systems of arable farming in the Carpathian region. *Visnyk LNAU: Agronomy*, 24, 38-44. doi: 10.31734/agronomy2020.01.038.

[16] Kramarev, S.M., Kramarev, O.S., Khristenko, A.O., Tokmakova, L.M., Zhuchenko, S.I., Syrovatko, V.A., Tsyova, Yu.A., & Syrovatko, K.V. (2015). Comparative evaluation of the content of mobile phosphorus in different genetic horizons of ordinary chernozem. *Bulletin of the Poltava State Agrarian Academy*, 1(2), 29-31. doi: 10.31210/visnyk2015.1-2.04.
[17] Martyniuk, S., Pikuła, D., & Kozieł, M. (2019). Soil properties and productivity in two long-term crop rotations differing with respect to organic matter management on an Albic Luvisol. *Scientific Reports*, 9, article number 1878. doi: 10.1038/s41598-018-37087-4.
[18] Nikitina, O.V., & Vasylenko, O.V. (2019). Agroecological impact of long-term use of fertilizers on the potassium fund of podzolized chernozem. *Taurian Scientific Bulletin*, 107, 335-340. doi: 10.32851/2226-0099.2019.107.44.
[19] Pinkovskyi, G.V., Mashchenko, Yu.V., & Tanchyk, S.P. (2019). Influence of nutrients on soil fertility and sunflower productivity in the Right Bank Steppe of Ukraine. *Taurian Scientific Encyclopedia*, 107, 145-150. doi: 10.32851/2226-0099.2019.107.19.
[20] Plisko, I.V., & Kutsova, K.M. (2023). Heterogeneity of the content of nitrogen compounds in some arable soils of the Left Bank Forest Steppe of Ukraine. *Bulletin of Agricultural Science*, 101(1), 5-13. doi: 10.31073/agrovisnyk202301-01.
[21] Ting-ting, X.I.N.G., An-dong, C.A.I., Chang-ai, L.U., Hong-ling, Y.E., Hong-liang, W.U., Sheng-chang, H.U.A.I., Jin-gu, W.A.N.G., Ming-gang, X.U., & Qi-mei, L.I.N. (2022). Increasing soil microbial biomass nitrogen in crop rotation application. *Journal of Integrativ Agriculture*, 21(5), 1488-1500. doi: 10.1016/S2095/3119(21)63673-0.
[22] Tsentilo, L.V., Tsyuk, O.A., & Melnyk, V.I. (2018). Nutrient content in the soil under the influence of fertilizers and tillage. *Bioresources and Nature Management*, 10(3), 164-169.
[23] Tsyuk, O., Tkachenko, M., Butenko, A., Mishchenko, Y., Kondratiuk, I., Litvinov, D., Tsiuk, Y., & Sleptsov, Y. (2022). Changes in the nitrogen compound transformation processes of typical chernozem depending on the tillage systems and fertilizers. *Agraarteadus*, 1(33), 192-198. doi: 10.15159/jas.22.23.
[24] Uzoh, I.M., Igwe, C.A., Okebalama, C.B., & Babalola, O.O. (2019). Legume-maize rotation effect on maize productivity and soil fertility parameters under selected agronomic practices in a sandy loam soil. *Scientific Reports*, 9, article number 8539. doi: 10.1038/s41598-019-43679-5.

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Гумусний стан та поживний режим чорнозему типового залежно від удобрення в короткоротаційних сівозмінах

Анотація. Система удобрення – найдієвіший фактор інтенсифікації технологій вирощування сільськогосподарських культур. Основою науково обґрунтованих систем застосування добрив, разом з отриманням запланованого рівня врожаю відповідної якості, актуальним є вивчення показників вмісту органічної речовини та поживного режиму ґрунту за ротацію сівозміни. Метою даного дослідження є визначення мінерального азоту, рухомого фосфору, обмінного калію і вмісту гумусу, в чорнозему типового за різних систем удобрення у короткоротаційних сівозмінах. Для вирішення проблеми родючості ґрунту важливим підходом є проведення польових і лабораторних досліджень для визначення змін гумусного стану за Тюріним, азотного, фосфорного, калійного режиму ґрунту за Мачигіним та дисперсійні методи для визначення достовірності експериментальних даних. В результаті проведених досліджень, встановлено, що найвищий вміст гумусу у ґрунті зафіксовано за органо-мінеральної системи удобрення на кінець другої ротації у зернопросапній на 0,13 % у порівняно з плодозмінною сівозміною. Застосування мінеральної системи удобрення за просапної сівозміни вміст гумусу зменшився на 0,12 %. Зростання гумусованості чорнозему типового зафіксовано за плодозмінної і зернопросапної сівозміни. Органо-мінеральна система удобрення тенденційно підвищувала вміст у грунті мінерального азоту у порівняні з іншими системами. Вміст мінерального азоту за мінеральної системи удобрення зменшився на 5,5 мг/кг грунту порівняно з варіантом без удобрення. За органо-мінеральної і мінеральної системи удобрення вміст рухових фосфатів зростав за всіх сівозмін. Вміст рухомого фосфору у просапній сівозміні істотного знижувався у порівнянні з плодозмінною і зернопросапною сівозміною. Найбільший вміст обмінного калію у грунті зафіксовано за мінеральної системи удобрення. Матеріали публікацій мають практичне значення при аналізі основних елементів мінерального живлення чорнозему типового в коротко ротаційних сівозмінах

Ключові слова: мінеральний азот; обмінний калій; соняшник; елементи живлення; агроценоз