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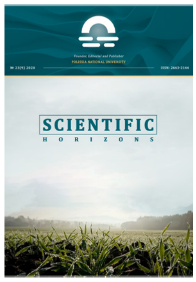

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Fractional Composition of Mineral Phosphates of Podzolized Chernozem after Prolonged Use of Fertilisers in Field Crop Rotation

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Abstract. The phosphate state of the soil is an important factor in forming its fertility. In this regard, the study of the phosphate state of different soil subtypes in different agrocenoses is relevant. Experimental data on changes in the content of gross phosphorus and its fractional composition in podzolized chernozem under the influence of long-term fertilisation are important for the effective use of fertilisers in the right-bank forest-steppe of Ukraine, determine its potential for providing plants with phosphorus, and are the theoretical basis for clarifying the standards for the rational use of high-cost phosphorous fertilisers. The purpose of the study was to investigate changes in the fractional composition of mineral phosphates of podzolized chernozem compared to fallow after the use of various fertiliser systems in the field crop rotation of the right-bank forest-steppe. In the soil from a layer of 0-20 cm, the content of mineral phosphates was determined by the Chang and Jackson method modified by Ginzburg-Lebedeva with photo colourimetric determination of phosphorus by the Denigs method modified by Truog-Mayer. Studies have shown that the loessial podzolized heavy loam chernozem has significant reserves of phosphorus potentially available for plant nutrition. After 55 years in the field crop rotation, depending on the characteristics of fertiliser, its content in the soil changed from 921 mg/kg to 2,565 mg/kg P_2O_5 (content of 1,008 mg/kg under fallow). The content of mineral phosphate fractions in podzolized chernozem is arranged in the following sequence: $Ca\text{-}P_{II}>Ca\text{-}P_{III}>Ca\text{-}P_{I}>Fe\text{-}P>Al\text{-}P$. The use of manure and mineral fertilisers increases the phosphorus content in all fractions of mineral phosphates. First of all, the share of active forms – $Ca\text{-}P_I$ and $Ca\text{-}P_{II}$ is growing up to 66-72% (with 64% content in fallow). According to the organo-mineral fertiliser system (option Manure 13.5 t + $N_{68}P_{101}K_{54}$), phosphorus between the fractions of mineral phosphates is distributed in the following ratio,%: $Ca\text{-}P_I$-7; $Ca\text{-}P_{II}$-40; $Ca\text{-}P_{III}$-28; Al-P-11; Fe-P-14. Phosphate mobility estimated by the indicator ($Ca\text{-}P_I$+ $Ca\text{-}P_{II}$): $Ca\text{-}P_{III}$ depends more on fertiliser doses than on fertiliser systems. High content of $Ca\text{-}P_{III}$ fraction in podzolized chernozem indicates the need to clarify the optimal content of mobile phosphorus compounds

Keywords: soil, fertiliser systems, gross phosphorus, calcium phosphates, aluminium phosphates, iron phosphates

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INTRODUCTION

The soils of Ukraine have an average ability to provide plants with phosphorus. Therefore, one of the important tasks of modern agricultural production is to restore and gradually increase its content in soils to create an optimal phosphate regime that ensures high and sustainable crop yields (Soltangheisi *et al*., 2020; Ginzburg, 1981). In the forest-steppe, the area of chernozems is podzolized by about 16% and they are most common on the Right Bank. Their profile is characterised by a combination of genetic traits inherent in chernozems typical of dark grey forest soils. The main processes of chernozem formation are: sod-forming process and migration of calcium bicarbonates along the profile. These processes remain leading, but in ploughed chernozems, they are quantitatively changed, because after ploughing, the sod-forming process is significantly inhibited due to a sharp decrease in the intake of plant residues (Bulygin *et al*., 2016). This leads to a weakening of the humus accumulation process and, accordingly, to the loss of humus by soils. According to H.M. Hospodarenko *et al.* (2018) the humus content in podzolized chernozem depends on the intensity of fertiliser use in the field crop rotation. With prolonged use of optimal fertiliser systems, its agrochemical state gradually stabilises.

In the chernozem zone, the effective fertility of soils and the effect of fertilisers are most affected by the supply of phosphorus to plants (Baluik *et al*., 2018). Even D.N. Prianishnikov (1952) believed that in order to revive the chernozems depleted by centuries-old agriculture, it is necessary to add phosphorus. The problem of phosphorus in agriculture is still quite important today. The phosphate level of soils is one of the important signs of their fertility (Vasbieva *et al*., 2021; Miroshnichenko *et al*., 2021; Nosko, 2017). Plants' assimilation of the optimal amount of phosphorus to produce a high yield depends on its soil reserves, mobility, and a number of conditions that affect its absorption (Marschner, 2012).

Experimental data on changes in the content of gross phosphorus and its fractional composition in podzolized chernozem under the influence of long-term fertilisation is the theoretical basis for the effective use of fertilisers in the right-bank forest-steppe of Ukraine, and the potential capabilities of this type of soil to provide plants with phosphorus is the theoretical basis for creating new standards for the rational use of high-cost phosphorous fertilisers on a regional scale.

The phosphate state of the soil largely reflects its genetic characteristics. The total phosphorus content, the nature of the profile distribution, the proportion of mineral compounds and their forms, and other indicators determine the type of soil development and the degree of soil cultivation (Menezes-Blackburn *et al*., 2018). This is conditioned by the peculiarities of interaction of phosphorus compounds with individual soil components (cations of soil solution, free iron and aluminium oxides, exchange bases of the soil absorption complex) with the establishment of stable hard-to-dissolve compounds. The content of phosphorus and its distribution by forms in soils has a zonal and subzonal character and is associated with both geological processes and anthropogenic transformation of modern soils under the influence of various factors (Baliuk *et al*., 2018; Schneider *et al*., 2019). In this regard, the study of the phosphate regime of podzolized chernozem under long-term application of different doses of fertilisers and fertiliser systems in the field rotation is relevant.

The main source of phosphorus in the process of soil development is the parent rock. Due to bio-displacement by plants, most of it accumulates in the upper layers of the soil profile. Phosphorus has a number of chemical properties that determine its versatile interaction with soil components, which contributes to the formation of a large number of compounds. This makes it difficult to develop methods for assessing the ability of soils to provide agricultural crops with phosphorus (Nosko, 2017; Kristenko, 2019). In phosphorus agrochemistry, the most important issue is the absorption of fertiliser phosphates by the soil, the level of which and the strength of the bond depends on the supply of plants with this element. Phosphorous fertilisers introduced into the soil undergo various transformations with the formation of organic and mineral phosphates. The ability of plants to absorb phosphorus from fertilisers does not depend on those compounds that were introduced, but on those that were formed in the soil. Therefore, to evaluate a particular phosphorous fertiliser and outline its rational use, i.e., the dose, method, and time of application, it is necessary to know what transformations it undergoes during interaction with the soil and what phosphates are formed in this case (Teicher *et al*., 2018). B.S. Nosko (2019) found that fertiliser phosphorus is distributed among phosphate fractions in the same way as their distribution in virgin soil, but this cannot be traced in all soils. For example, in chernozems, newly formed phosphates form a structure of the phosphate fund that is not identical to its natural counterparts (Nunes *et al*., 2020). It has been shown that the features of phosphorus conversion of organic and mineral fertilisers, the properties of newly formed phosphates depend on the mineralogical composition of the soil, the content of organic compounds (Kyrychenko, 2015; Lisoval *et al*., 1984), fertiliser doses and forms, soil cultivation, but the main factor in these transformations is the acidity of the soil environment (GInzburg, 1981; Vasbieva, 2021; Sheil *et al*., 2016).

According to R.S. Truskavetsky & Yu.L. Tsapko (2016), the use of mineral fertilisers increases the content of potentially available phosphates in the soil. Residual phosphates of applied fertilisers are more mobile than natural compounds. In a long-term experiment, the degree of provision of carbonate phosphates to chernozem and changes in their group (qualitative) composition depended on the doses and duration of fertiliser application. At low doses of phosphorous fertilisers, changes are usually insignificant, since doses that exceed the removal of phosphorus by crops accumulate in all soil residues, which are distributed among all fractions of soil phosphates (Volkogon *et al*., 2019; Zagorcha, 1990). Consequently, the features of the distribution of phosphorus between them during fertiliser application remain rather neglected and require further investigation.

The purpose of the study was to identify and theoretically substantiate the nature and line of changes in the phosphate fund of podzolized chernozem after the prolonged application of fertilisers in crop rotation. The main task of the research is to characterise the phosphate state of podzolized chernozem by identifying patterns of changes under the influence of mineral, organic, and organo-mineral fertiliser systems; to assess the fractional composition of mineral phosphates in agrocenosis with different fertiliser systems in crop rotation.

MATERIALS AND METHODS

The study was conducted in a stationary experiment (NAAS Certificate No. 88), laid in the experimental field of the Uman National University of Horticulture (Zaryshniak *et al*., 2014), which is located in the Mankivskyi natural and agricultural area of the right-bank forest-steppe, which is based on a 10-field crop rotation with a typical set of field crops for the region, deployed in all fields (Table 1) (Zaryshniak *et al*., 2014).

Table 1. *Fertiliser distribution scheme for crops in a field crop rotation in a stationary experiment (manure, t/ha; mineral fertiliser, kg/ha)*

Experiment variant	Fertiliser option	Clover	Winter wheat	Sugar beet	Corn	Peas	Winter wheat	Corn for silage	Winter wheat	Sugar beet	Spring barley + Clover
Control (without fertilisers)	–	–	–	–	–	–	–	–	–	–	–
$N_{45}P_{45}K_{45}$	N	–	45	90	50	10	45	50	45	90	25
	P_2O_5	–	45	90	50	10	45	50	45	90	25
	K_2O	–	45	90	50	10	45	50	45	90	25
$N_{90}P_{90}K_{90}$	N	80	90	135	100	30	90	100	90	135	50
	P_2O_5	80	90	135	100	30	90	100	90	135	50
	K_2O	80	90	135	100	30	90	100	90	135	50
$N_{135}P_{45}K_{45}$	N	50	135	180	200	60	135	200	135	180	75
	P_2O_5	50	135	180	200	60	135	200	135	180	75
	K_2O	50	135	180	200	60	135	200	135	180	75
Manure 9	Manure	–	–	30	–	–	30	–	–	30	–
Manure 13.5	Manure	–	–	45	–	–	45	–	–	45	–
Manure 18	Manure	–	–	60	–	–	60	–	–	60	–
Manure 4.5 t+$N_{22}P_{34}K_{18}$	N	–	22.5	30	50	–	22.5	22.5	22.5	30	25
	P_2O_5	–	22.5	67.5	50	10	22.5	50	22.5	67.5	25
	K_2O	–	22.5	15	47.5	10	22.5	–	22.5	15	25
	Manure	–	–	15	–	–		15	–	15	–
Manure 9 t+$N_{45}P_{68}K_{36}$	N	–	45	60	100	20	45	50	45	60	25
	P_2O_5	25	45	135	100	20	45	50	45	135	75
	K_2O	20	45	30	100	20	45	–	45	30	25
	Manure	–	–	30	–	–	–	30	–	30	–
Manure 13.5 t+$N_{68}P_{101}K_{54}$	N	–	67.5	90	150	20	67.5	75	67.5	90	47.5
	P_2O_5	50	67.5	202.5	150	30	67.5	100	67.5	202.5	75
	K_2O	17.5	67.5	45	150	30	67.5	–	67.5	45	50
	Manure	–	–	45	–	–	–	45	–	45	–

The soil is classified as loessial podzolized heavy loamy chernozem. Before laying the experiment in 1964, a humus content according to the Tyurin method (DSTU 4289:2004, 2005) was 3.31%; pH_{KCl} – 6.2; nitrogen content of easily hydrolysed compounds according to the Tyurin-Kononova (Tyurin & Kononova, 1934) – 48 mg/kg; mobile compounds of phosphorus (122 mg/kg) and potassium (135 mg/kg) according to the Chirikov (DSTU 4115:2002, 2003). The experiment uses organic, mineral, and organo-mineral fertiliser systems with single, double, and triple levels of saturation with the main elements of nutrition of the crop rotation area. Single-dose of mineral fertilisers – $N_{45}P_{45}K_{45}$, organic – 4.5 tonnes of manure per 1 ha of crop rotation area. According to the organo-mineral fertiliser system, the doses of the main nutrients are equal to the corresponding variants of the mineral system. The area of the experimental site of the experiment variant – 180 m^2, length – 18 m, and width – 10 m. Semi-rotted cattle manure, ammonium nitrate, granulated superphosphate, and potassium chloride were used in the experiment. Since long-term cultivation processes do not allow monitoring changes in the soil from the natural state to the one that has developed during land use, the method of comparison with the natural analogue – the fallow near the site was used for comparison.

For analytical studies, in 2020, soil samples were selected from 0-20 cm layer in accordance with the requirements of DSTU 4287:2004 and DSTU ISO 11464:2007. The gross phosphorus content was determined in accordance with DSTU 4290 (DSTU 4290:2004, 2005). Mineral phosphates were determined by the Chang and Jackson method in the Ginzburg & Lebedeva modification (Ginzburg & Lebedeva, 1971), the essence of which is to treat soil samples with various solvents in the following sequence – 1% solution of ammonium sulphate and 0.25% ammonium molybdate, 0.5% acetic acid and 0.25 % am-monium molybdate, 0.5% solution of ammonium fluoride, 0.1 % solution of caustic acid sodium, 0.5 % sulphuric acid. Phosphorus determination was performed photocolourimet-rically using the Denigs method modified by Truog-Mayer (Tyurin & Kononova, 1934).

Statistical processing of the research results contained was carried out using the Microsoft Office and STATISTICA 12 software suites.

RESULTS AND DISCUSSION

Studies have shown that the use of manure and mineral fertilisers causes changes in phosphorus reserves in the soil (Fig. 1).

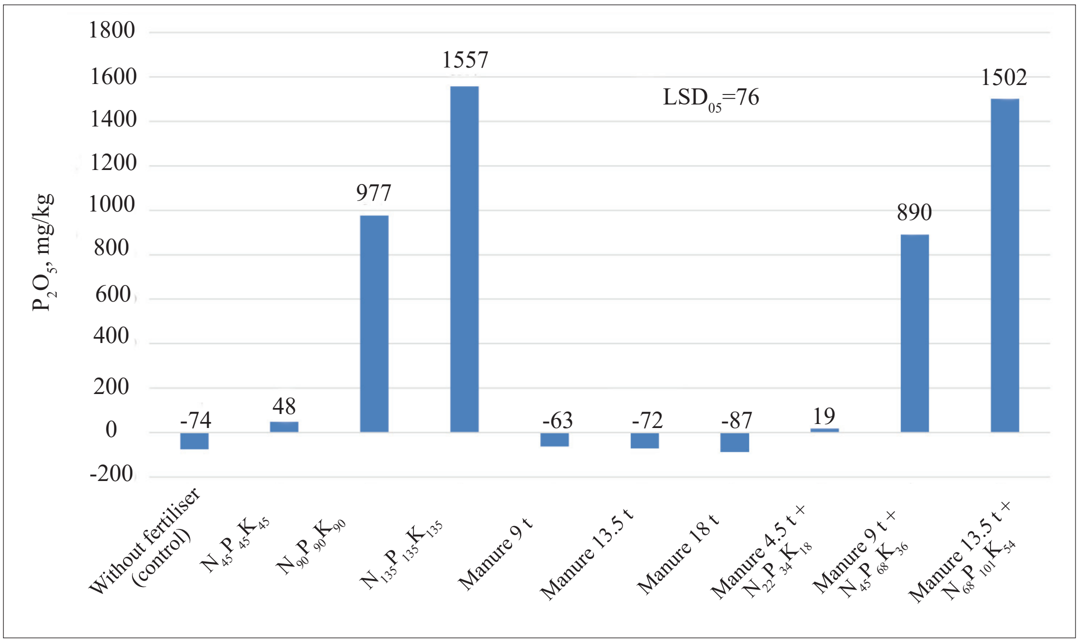

Figure 1. *Changes in gross phosphorus content in 0-20 cm soil layer after long-term (55 years) use of fertilisers in crop rotation compared to fallow (1,008 mg/kg)*

The phosphorus content in the soil varies depending on the doses of fertilisers and fertiliser systems. There is a very strong correlation between its content and the doses of phosphorus introduced (r=0.99). This is explained both by the removal of phosphorus by crops, and by its movement along the soil profile mechanically during its cultivation and in the forms of complex organo-mineral compounds.

Mineral phosphates in the 0-20 cm layer of fallow make up 61% of the gross phosphorus content, or 615 mg/kg. In this case, phosphorus is distributed between the fractions in the following ratio, %: Ca-P_I-5; Ca-P_{II}-42; Ca-P_{III}-36; Al-P-9; Fe-P-8 (Fig. 2). High-base calcium phosphates occupy the main share of mineral phosphate compounds. The fertiliser does not affect the structure of mineral phosphates. It mostly depends on the acidity of the soil solution and the content of carbonates in it (Ginzburg, 1981; Kristenko, 2019; Truskavetsky &Tsapko, 2016). O.A. Biriukova *et al.* (2010) found that the amount of phosphorus absorbed by plants depends on the ratio of calcium exchange to the amount of total carbonates in the soil. There is a certain equilibrium between the exchange calcium and the total content of carbonates of various nature in these soils, the displacement of which reduces the availability of phosphorus. This is explained by the formation of hard-to-dissolve calcium phosphates.

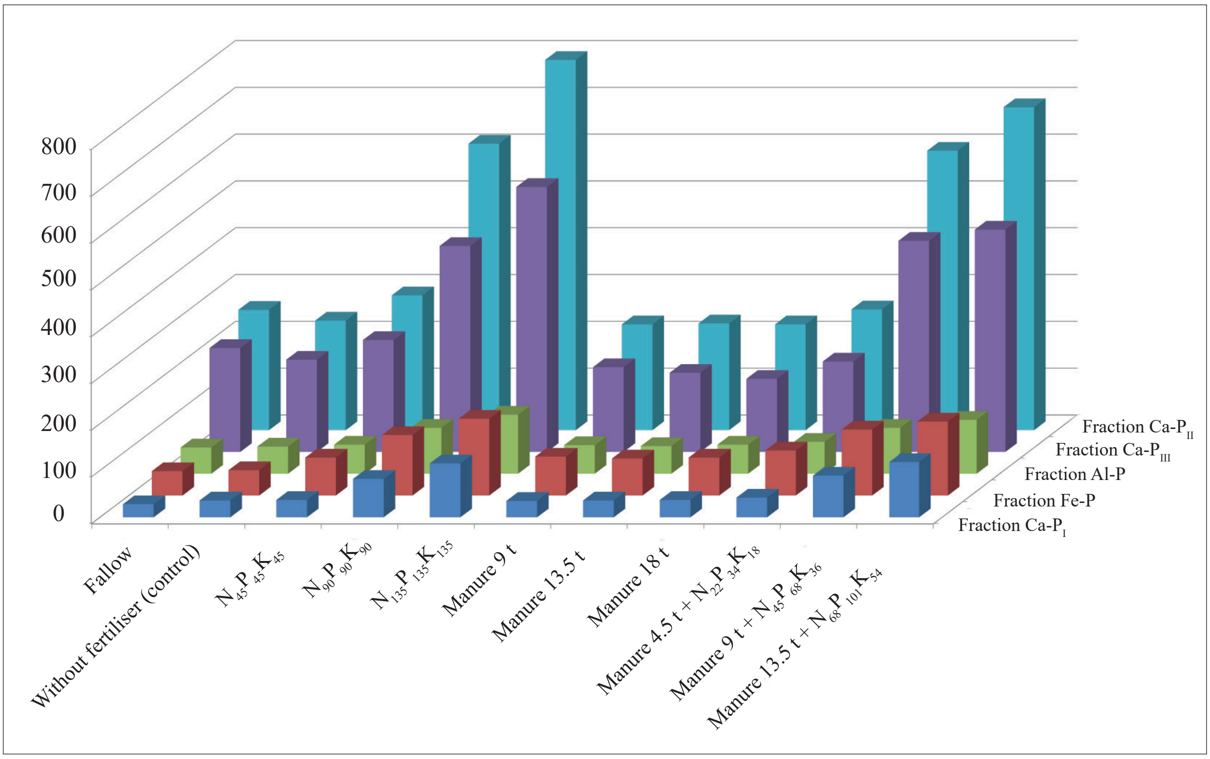

Figure 2. *Fractional composition of mineral phosphates in 0-20 cm soil layer after long-term (55 years) use of fertilisers in crop rotation, mg/kg*

Long-term cultivation of crops without the use of fertilisers did not significantly affect both the content of mineral phosphates and their distribution between fractions. This can be explained by the bio-displacement of phosphorus from the lower soil layers by plant root systems (Karengina *et al.*, 2020). The phosphate content of the fraction Ca-P$_{I}$ which is represented by phosphates of alkaline and alkaline earth metals, is 28-118 mg/kg of soil, depending on the experimental variant and depends on the content of gross phosphorus in the soil (r=0.98). The content of dissimilar calcium phosphates (Ca-P$_{II}$), which is less accessible to plants, is much larger – 226-791 mg/kg. A significant proportion of the amount of mineral phosphates is occupied by three substituted calcium phosphates (Ca-P$_{III}$) – 28-36%, depending on the experiment variant. There is a close correlation between the content of gross phosphorus in the soil and its distribution in different fractions of mineral phosphates (r=0.89-0.99).

The use of organic and mineral fertilisers increases the phosphorus content in all fractions of mineral phosphates. First of all, there is an accumulation of phosphates of the fraction Ca-P$_{I}$, which is the most valuable for phosphorous nutrition, and also in the faction Ca-P$_{II}$, which is its immediate reserve. According to (Menezes-Blackburn *et al.*, 2018), the intake of organic substances into the soil with both organic fertilisers and plant residues, improves the water-physical properties of the soil, increases their biological activity, and stabilises the nitrogen state. At the same time, the intensity of transformation processes of mineral and organic phosphates in the soil changes accordingly, which contributes to their better assimilation by plants.

Attention is drawn to the almost identical content of Al-P and Fe-P fractions on the fallow and the increase in the content of the latter with prolonged use of fertilisers, especially mineral ones. This can be explained by an increase in the binding of phosphate ions to iron and a decrease in aluminium with the acidification of the soil medium (Rosso *et al.*, 1995). Notably, aluminium-bound phosphorus is 1-6 times more accessible to plants than iron phosphates, and iron phosphates are 8-18 times more accessible than calcium phosphates (Sheil *et al.*, 2016). This also explains the change in the content of the fraction Ca-P$_{III}$. Despite the increase in the content of this fraction in the soil at high doses of fertilisers of the mineral and organo-mineral systems to 440-566 mg/kg (with a content of 222 mg/kg on fallow), in the composition of mineral phosphates, their content respectively decreased from 36 to 28-34 %. At the same time, for example, according to the organo-mineral fertiliser system (option Manure 13.5 t + $N_{68}P_{101}K_{54}$), phosphorus between the fractions of mineral phosphates is distributed in the following ratio, %: Ca-P$_{I}$-7; Ca-P$_{II}$-40; Ca-P$_{III}$-28; Al-P-11; Fe-P-14. That is, in comparison with the fallow and plots without fertilisers, the share of phosphorus in active forms has increased. Similar data were obtained on carbonate chernozem (Zagorcha, 1990). Long-term systematic use of mineral fertilisers and their combination with organic ones contributes to an increase in the amount of mineral phosphates – in some variants of the experiment ($N_{90}P_{90}K_{90}$, $N_{135}P_{135}K_{135}$, Manure 9 t+$N_{45}P_{68}K_{36}$, Manure 13.5 t+$N_{68}P_{101}K_{54}$) up to 1,361-1,762 mg/kg with content in fallow of 615 mg/kg (Table 2).

***Table 2**. Distribution by fractions of mineral phosphates in the soil layer 0-20 cm after long-term fertilisation in crop rotation, 2020*

Experiment variant	Amount, mg/kg of soil				$\frac{Ca\text{–}PI + Ca - PII}{Ca\text{–}PIII}$	$\frac{\Sigma\, Ca\text{–}P}{Al\text{–}P + Fe\text{–}P}$
	Mineral phosphates	Active forms	Ca-P	Al-P+Fe-P		
Fallow	615	393	507	108	1.28	4.69
No fertiliser (control)	579	382	467	112	1.37	4.17
$N_{45}P_{45}K_{45}$	707	468	564	143	1.36	3.94
$N_{90}P_{90}K_{90}$	1,361	921	1,134	227	1.58	5.00
$N_{135}P_{135}K_{135}$	1,762	1,196	1,472	290	1.60	5.08
Manure 9 t	586	405	442	144	1.44	3.07
Manure 13.5 t	571	402	433	138	1.56	3.14
Manure 18 t	562	406	419	143	1.69	2.93
Manure 4.5 t + $N_{22}P_{34}K_{18}$	657	464	493	164	1.55	3.01
Manure 9 t + $N_{45}P_{68}K_{36}$	1,376	925	1,137	239	1.61	4.76
Manure 13.5 t + $N_{68}P_{101}K_{54}$	1,586	1,081	1,283	273	1.70	4.69

However, relative to the gross phosphorus content, their number has changed less significantly – only at the second and third levels of the mineral and organo-mineral fertiliser systems, their content is 62-69%, while the content on fallow – 61%. Fertiliser systems and fertiliser doses have only a small effect on the distribution of phosphorus between mineral phosphate fractions. First of all, it is necessary to note an increase in the number of active forms in the composition of mineral phosphates – from 64% on the transfer to 66-72%, depending on the characteristics of the fertiliser. This is mainly conditioned by the fractions Ca-P_I and Fe-P. Thus, according to the organo-mineral fertiliser system, the content of phosphates of the fraction Ca-P_I increased by 14-90, and Fe-P – by 44-106 mg/kg of soil compared to untilled virgin land. An increase in these fractions in the composition of mineral phosphates was also observed in other subtypes of chernozems (Soltangheisi *et al*., 2020; Vasbieva, 2021).

The sum of active forms of phosphates in areas without fertilisation, under the organic fertiliser system and at the first levels of the mineral and organo-mineral fertiliser system almost did not change and was in the range of 382-468 mg/kg (with the content of fallow of 393 mg/kg). This can be explained by the negative balance of phosphorus and its bio-displacement by the root systems of agricultural crops. The increase in the content of calcium phosphates in the soil was slower than the sum of aluminium and iron phosphates (Al-P+Fe-P). However, the mobility of phosphates estimated by the indicator (Ca-P_I+Ca-P_{II}): Ca-P_{III}, significantly depended on fertiliser doses and less on fertiliser systems. The highest rate of their mobility – 1.70 – was formed by applying 13.5 t/ha of manure + $N_{68}P_{101}K_{54}$ per 1 ha of crop rotation area. For fallow areas and areas without fertilisers, this indicator is significantly lower – 1.28 and 1.37, respectively.

With a negative balance of phosphorus in the soil of crop rotation, the content of calcium phosphates available to plants (Ca-P_I+ Ca-P_{II}) decreases, as do phosphates of sesquioxides (Al-P+Fe-P) (Khristenko, 2019; Hospodarenko, 2002; Sheudzhen, 2018). In the test soil, most phosphorus accumulates in the form of calcium phosphate, which is 3-5 times more, depending on the experimental variant, than in other phosphates. Therefore, the study of the fractional composition of podzolized chernozem shows that with long-term cultivation of field crops, there is an increase in the content of mineral phosphates in the soil regardless of the systems and levels of fertiliser application. Due to Fertilisers, the proportion of active forms in their composition increases, primarily fractions Ca-P_I and Fe-P. The increase in the content of the Fe-P fraction is explained by the acidification of the soil. The application of phosphorous fertilisers in doses exceeding the extraction of phosphorus from the soil affects all fractions of its phosphate fund.

It is worth noting that podzolic chernozem fallow contains only 65 mg/kg of mobile forms of phosphorus, which indicates a possible high efficiency of using phosphorous fertilisers. In the soils of the forest-steppe zone, agricultural crops react to phosphorous fertilisers with the content of mobile forms of phosphorus up to 250 mg/kg (Kristenko, 2019). This is conditioned by the high content of the Ca-P_{III} fraction in the soil. However, these phosphates have a low degree of mobility – 0.095 mg P_2O_5/l and do not take a direct part in plant nutrition, but pass into 0.5 m acetate extract in large quantities. Therefore, based on the obtained experimental data, it can be concluded that the optimal content of mobile phosphates (150 mg/kg) accepted for the podzolized chernozem of the right-bank forest-steppe is underestimated and needs to be clarified.

CONCLUSIONS

1. Podzolized chernozem of the right-bank forest- steppe has high potential capabilities in terms of the ability to provide field crops with phosphorus. After 55 years of applying various doses of fertilisers and fertiliser systems, the gross phosphorus content is 0.09-0.27% P_2O_5 (according to the content on fallow – 0.10%).

2. Fertiliser systems and fertiliser doses have little effect on the distribution of phosphorus between mineral phosphate fractions. At the same time, the share of active forms increases – from 64% on the transfer to 66-72%, depending on the characteristics of the fertiliser. This is mainly conditioned by the fractions Ca-P_I and Fe-P. According to the organo-mineral fertiliser system, the content of phosphates of the fraction Ca-P_I increased by 14-90, and Fe-P – by 44-106 mg/kg of soil compared to untilled virgin land.

3. The content and mobility of phosphorus compounds in the soil significantly depend on the fertiliser systems. Thus, in the organic fertiliser system, mineral phosphates make up 61-62%, in the organo-mineral system – 64-72, and in the mineral system – 67-69% of the gross phosphorus content.

4. Calcium phosphates predominate in the composition of soil mineral phosphates. By content, mineral phosphates make up the following series: Ca-P_{II}>Ca-P_{III}>Ca-P_I>Fe-P>Al-P.

5. The phosphate level of podzolized chernozem can be significantly improved by creating a positive balance of phosphorus due to the introduction of organic and mineral fertilisers. This is facilitated by a number of factors: the preservation of phosphorus in compounds potentially available to plants and the absence of migration along the soil profile.

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Фракційний склад мінеральних фосфатів чорнозему опідзоленого після тривалого застосування добрив у польовій сівозміні

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Анотація. Фосфатний стан ґрунту є важливим чинником формування його родючості. У зв'язку з цими дослідження фосфатного стану різних підтипів ґрунтів у різних агроценозах є актуальним. Експериментальні дані про зміни вмісту валового фосфору та його фракційний склад у чорноземі опідзоленому під впливом тривалого удобрення мають важливе значення для ефективного використання добрив у Правобережному Лісостепу України, визначають потенційні його можливості щодо забезпечення рослин фосфором і є теоретичною основою уточнення нормативів раціонального застосування високовартісних фосфорних добрив.Метою досліджень стало вивчення зміни фракційного складу мінеральних фосфатівчорнозему опідзоленогопорівняно з перелогом після застосування різних систем удобрення в польовій сівозміні Правобережного Лісостепу. У ґрунті з шару 0–20 смвизначали вміст мінеральних фосфатів методом Чанга та Джексона у модифікації Гінзбург-Лебедєвої з фото колориметричним визначенням фосфору за методом Деніже модифікованим Труог-Майєр. Дослідження показали, що чорнозем опідзолений важкосуглинковий на лесі має значні запаси потенційно доступного для живлення рослин фосфору. Через 55 років у польовій сівозмінізалежно від особливостей удобрення вміст його у ґрунті змінився від 921 мг/кг до 2565 мг/кг P_2O_5 (за вміступід перелогом 1008 мг/кг).Вміст фракцій мінеральних фосфатів у чорноземі опідзоленому розміщується у такій послідовності: $Ca\text{-}P_{II}>Ca\text{-}P_{III}>Ca\text{-}P_{I}>Fe\text{-}P>Al\text{-}P$. Застосування гною і мінеральних добрив сприяє збільшенню вмісту фосфору в усіх фракціях мінеральних фосфатів. Насамперед зростає частка активних форм – $Ca\text{-}P_I$ і $Ca\text{-}P_{II}$ до 66–72 % (за вмісту на перелозі 64 %). За органо-мінеральної системи удобрення (варіант Гній 13,5 т + $N_{68}P_{101}K_{54}$) фосфор між фракціями мінеральних фосфатів розподіляється в такому відношенні, %: Ca-PI-7; $Ca\text{-}P_{II}$-40; $Ca\text{-}P_{III}$-28; Al-P-11 і Fe-P-14. Рухливість фосфатів, оцінена за показником($Ca\text{-}P_I+Ca\text{-}P_{II}$): $Ca\text{-}P_{III}$ більше залежить від доз добрив, ніж від систем удобрення. Високий вміст у чорноземі опідзоленому фракції $Ca\text{-}P_{III}$ вказує на необхідність уточнення оптимального вмісту рухомих сполук фосфору

Ключові слова: ґрунт, системи удобрення, валовий фосфор, фосфати кальцію, фосфати алюмінію, фосфати заліза