UDC 631.811.2

B. Nosko, academician of the NAAS, doctor of agricultural sciences
V. Babynin, Ye. Gladkih,
candidates of agricultural sciences
National scientific center "Institute for soil science and agrichemistry research named after O.N. Sokolovsky"

BALANCE OF PHOSPHORUS IN SOIL AND FARMING AGRICULTURE OF UKRAINE

The purpose. To study links between amount of applied phosphate fertilizers and the content of residual phosphates, balance of phosphorus and duration of afteraction of fertilizers. **Methods.** Comparative-statistical methods of probes, short- and long-term observations of agrochemical soil characteristics. Laboratory-analytical probes based on the standardized procedures. **Results.** Dynamics is determined of changes of phosphatic regimen of typical black earth on the basis of generalization of probes on paleocrystic long fallow and alternatives with different levels of saturation with mineral and organic fertilizers. **Conclusions.** Duration of influence (during 25 years of after- action) is proved of reserve importation of phosphate fertilizers in dose of 1800 kg/hectare on the background of muck upon conservation in soil of the heightened content of mobile phosphorus at the level of 11,6 mg of P2O5 for 100 g of soil which differs from natural analog by greater accessibility to plant nutrition.

Key words: typical black earth, mobile phosphorus, balance, residual phosphates, after-action of phosphate fertilizers.

Phosphorus plays a special role in the life of plants; it serves as a regulator of energy balance because it is capable of forming compounds with a large amount of energy released in the process of their hydrolysis. The transfer of hereditary features, which are "recorded" in screw-like DNA molecules and RNA, are also carried out by phosphorus compounds included in these molecules [7]. The obligatory presence of phosphorus is the assimilation of carbonic acid, which is the material energy basis of the existence of animals and humans on earth.

The availability of plants with sufficient phosphates depends mainly on their reserves in the soil, the degree of their mobility, as well as many other factors, in particular from the reaction of the soil solution, the optimal ratio of the mobile forms of nitrogen and phosphorus, the activity of microbiological processes in the soil, etc. [6, 8, 15, 16].

The gross phosphorus content in the humus profile is the result of its biological transfer from parent rock, which has an uneven amount of this element, depending on the mineralogical composition. According to Kudejarova [5] the average sedimentary rocks - sandstones, clay shales and carbonate rocks - are characterized by the content of P2O5, respectively, 0.10; 0.17 and 0.07%. According to the data of Polupan and Velichko [13], the content of P_2O_5 in Ukraine is based on the content of physical clay and varies from 0.04 to 0.07 in fluvioglacial rocks of Polissya, to 0.07-0.11% in forest and forest-like rocks of the forest-steppe and Steppe. In this case, the bioaccumulation of P_2O_5 in the arable layer with respect to its content in the parent rock varies from 109% in sod-podzolic sandy soils and sandy soils to 170% in typical chernozem, and reaches 570% in burozem.

In the process of genesis of soils, a specific phosphate regime for each type of soil is formed, characterized by a certain ratio of mineral and organic phosphates and their fractions, the presence of mobile forms of phosphorus, and the degree of mobility of phosphorus and phosphate potential. Phosphate regime is a characteristic feature of each type of soil and, first of all, the result of the ratio of the processes of humification and mineralization of organic matter.

Modern ideas about the phosphate soil regime are based on the fact that plants absorb phosphorus in the form of orthophosphates ($H_2RO_4^-$, NRO_4^-, RO_4^{3-}), which are directly in the soil solution. However, we must bear in mind that the transition of phosphates to soil solution is not only a dynamic process, but also depends on a number of factors:

- Stocks of all forms of natural phosphates in compounds of varying degrees of strength;
- Residual amount of phosphorus from previously applied fertilizers;
- Soil absorption capacity relative to phosphate ions;
- Conditions that affect the transformation processes (temperature, humidity, acidity, cationic composition of the absorbing complex, etc.);

- Activity of the root system, its absorbing capacity, which depends on the type of crop and the conditions of its cultivation.

During agricultural use, the phosphate regime of soils varies depending on the level of intensification of farming, primarily on the amount of phosphorus mineral (or organic) fertilizers applied to the soil. It has been proved that, with a positive balance of phosphorus, residual phosphate compounds accumulate in the soils, which differ from their natural counterparts and are characterized by a higher degree of mobility [9].

Even at the beginning of the twentieth century, Prof. Egorov proposed calling the applying of soils with phosphorus a quantitative measure of their cultivation [3].

At the same time, publications on the effect of residual phosphates on crop yields and the effectiveness of fertilizers, and especially the duration of their aftereffect on different soil types, do not provide a valid answer to these questions.

The aim of studies in the stationary experiment is studying the relationship between the amount of phosphorus fertilizers applied and the content of residual phosphates, the balance of phosphorus and the duration of their aftereffect.

Methods of research. Studies were carried out by the Agrochemistry Department NSC "ISSAR" in long term and temporary field experiments. As far back as 1969, a long-term stationary experiment was begun on Chernozem typical at the ISSAR Grakivske Experimental Station in Kharkiv region, East Ukraine. Prior to soil sampling, six rotations of 6-field crop rotation (vetch- and-oats for green forage, winter wheat, sugar beet, barley, maize silage, winter wheat) had been completed. Before application of fertilizers, showed pH(KCl) 5.5, humus content 3.9–4.5%, total N 0.22%, total P 0.12%, and total K 2.05%.

During the period 1969-83 three high-dose applications of mineral fertilizers (200, 400 and 600 kg/ha) were made to create four levels of nitrogen, phosphate, potash and nitrogen-phosphorus-potassium agrochemical backgrounds (natural, medium, heightened and high). The experimental field was laided out in 360 variants with different doses, types of fertilizers, and frequency of their application.

Soil samples were taken from the plow layer in the variants P_{1800} + 140 t/ha manure for 6 crop rotation (reserve application, aftereffect from 1983). And absolute control (without fertilization). To analyze the materials of monitoring surveys on the content of mobile phosphates and the balance of phosphorus in agriculture, the data of the agrochemical service were used, which were published in reference books [1, 2], as well as in statistical compilations.

Results and discussion. The plowing of virgin land caused significant changes in the ratio of the processes of humification and mineralization of organic substances. During two rotations of a six-peak crop rotation (during 1969-1982), the total content of humus in the plow layer decreased by 20% (in comparison with the initial position), simultaneously the fertilized variants doubled the amount of labile humus. At the same time, the content of organic phosphates on the control variant decreased from 62.2 mg P2O5 per 100 g soil to 38.8 mg, which is due to the active mineralization of humus.

For 6 rotation on the variant of experiment “absolute control”, the negative balance of phosphorus reached 734 kg P_2O_5 per hectare, but this did not affect the content of mobile forms of phosphate, which during 31 years fluctuated in the arable layer from 5.5 to 4.2 mg P_2O_5 per 100 g soil (Figure 1). Some increase in their content in the first years after plowing the deposit is due to the mineralization of organic phosphates. This indicates a large buffer capacity of typical chernozem. Due to this, a certain equilibrium of the content of phosphorus mobile forms is constantly maintained in the soil.

The positive balance of phosphorus (+880 kg / ha) was achieved in the soil on the variant of reserve application of P_{1800} (aftereffect from 1983, the duration of aftereffect of 25 years), despite the increase the total phosphorus carry-over with yields of agricultural crops to 1_{200} kg/ha P_2O_5 and the content of mobile phosphates (in the extract 0.5N CH3COOH) at the end of the sixth rotation exceeded the corresponding absolute control indicators by more than two times (Fig. 2). In previous studies [12] it was established that the residual phosphates of fertilizers in soil differ from natural phosphorus compounds, primarily by an increased degree of mobility and greater availability for plant nutrition.

As shown by the carried out studies [11], the dynamics of phosphate residual forms content in the arable layer of the chernozem typical occurs due to removal with crop yields, transformation into inaccessible forms for plants - about 15%, migration in the profile to a depth of 60 cm - 12%. But in spite of these additional factors reducing the mobile forms of phosphorus, after 31 years the application of phosphorus fertilizers in the soil is preserved their increased content (Figure 2). This indicates the formation of a certain balanced system of phosphate regime, which contributes to an increase in the effective fertility of chernozem and can characterize the degree of cultivation.

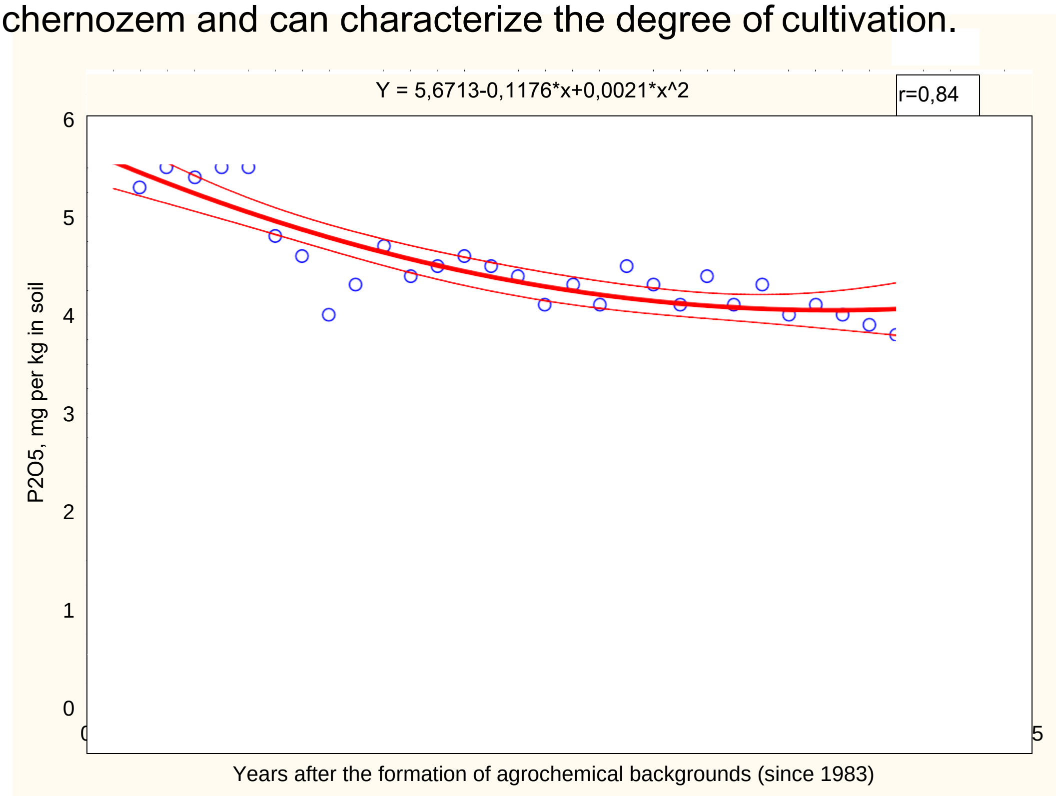

Fig. 1. Dynamics of the phosphorus mobile forms content in chernozem typical for 31 years on a variant without the use of fertilizers

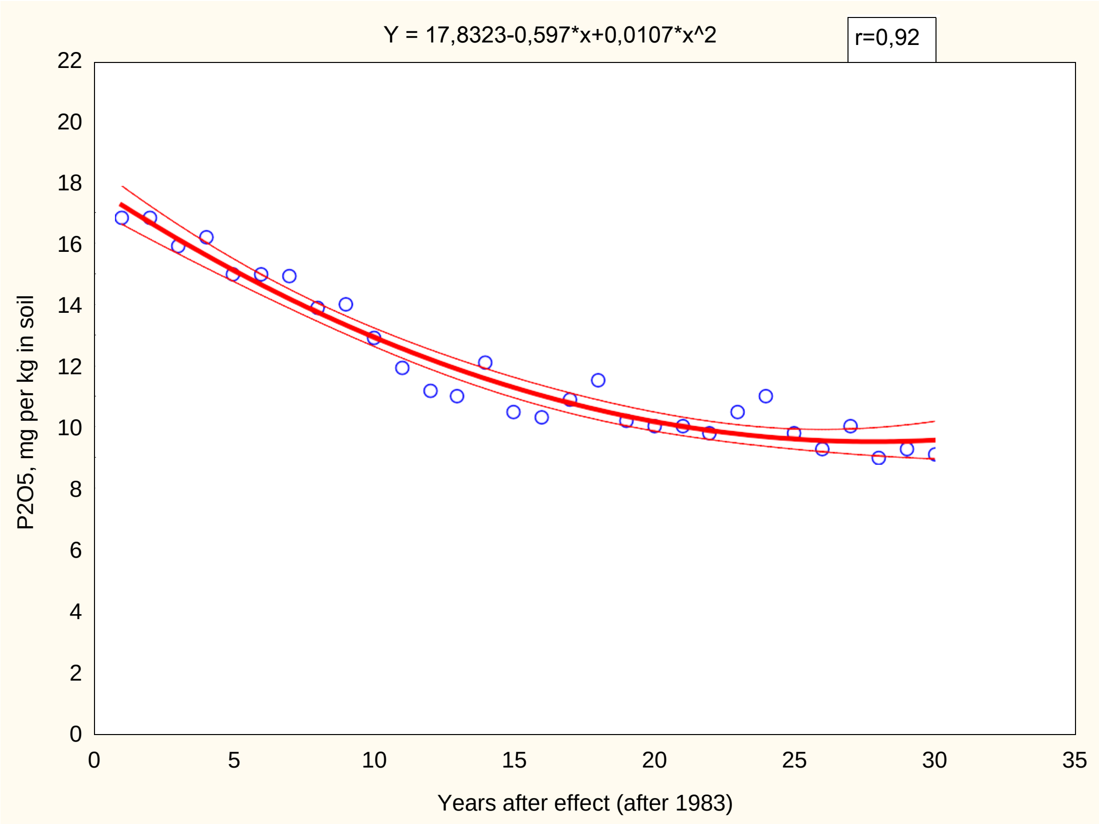

Fig. 2. Dynamics of the phosphorus mobile forms content in chernozem typical on agrochemical background “P_{1800} (in stock) +140 t/ha manure”

Accumulation of residual phosphates in soils is observed even with the use of moderate doses of phosphorus fertilizers, as evidenced by the results of monitoring studies of the agrochemical service.

In the 60 years of the last century in the Soviet Union was a crisis in the production of agricultural products. After a 2-3-year break, when the gross harvest was increased due to plowing of virgin lands, the yield of cereals and other crops decreased again. It was recognized that real positive changes in agriculture can only be achieved through intensification of agriculture and, first of all, comprehensive chemistry through the implementation of a broad program for the growth of fertilizer production, chemical melioration and plant protection products.

In Ukraine for the period from 1966-1970 to 1986-1990, the average annual volume of mineral fertilizer use increased from 46 to 148 kg of active ingredient (NPK) per hectare or in 3.2 times (Table 1).

1. Dynamics of the average annual volume of use of mineral fertilizers in Ukraine agriculture [4]

Years	NPK,	Including		
	of active ingredient	N	P_2O_5	K_2O
1966-1970	46	20	14	12
1971-1975	84	40	22	22
1976-1980	111	52	27	32
1981-1985	125	60	31	34
1986-1990	148	65	41	42
1991-1995	73	34	21	18
1196-2000	19	15	3	1
2001-2005	24,5	18	4	2,5
2006-2010	50,9	35,3	8,3	7,3
2011	68	48,4	10,5	9,1
2012	72	49,8	11,8	10,4
2013	79	55,2	12,5	11,3

The intensity of the total nutrients balance in Ukraine for the period from 1986 to 1990 reached an amount of NPK 102%, including nitrogen - 96, phosphorus - 165%, potassium - 86% (Table 2).

2. Dynamics of the general balance of nutritive elements in the agriculture of Ukraine for the period 1971-1990 [2]

Balance sheet items / Indicators	Inputs, kg per ha	Outputs, kg per ha	Balance, kg per ha	Intensity of the total nutrients balance, %
		1971-1975		
N	60,8	74,3	-13,5	81,8
P_2O_5	29,4	25,5	3,9	115,3
K_2O	44,0	72,0	-28	61,1
Total	134,2	171,8	-37,6	78,1
		1976-1980		
N	75,0	85,0	-10,0	88,2
P_2O_5	39,1	29,0	10,1	134,5
K_2O	61,8	78,7	-16,9	78,5
Total	175,9	192,7	-16,8	91,3
		1981-		

		1985		
N	84,6	83,4	1,2	101,3
P_2O_5	42,7	27,7	15,0	153,8
K_2O	70,8	78,8	-8,0	89,6
Total	198,1	189,9	8,2	104,3
		1986-1990		
N	91	95	-4	95,8
P_2O_5	52,5	31,9	20,6	164,6
K_2O	79,5	92,0	-12,5	86,4
Total	223,0	218,9	4,1	101,9

The annual excess of phosphorus inputs with fertilizers relative to its outputs with yields was more than 21.0 kg per ha, which undoubtedly contributed to a general increase in its weighted average content in arable soils due to the accumulation of residual phosphates. According to B. Nosko at the end of the fifth round of the agrochemical survey, the content of phosphorus grew (on average in Ukraine) from 7.1 to 10.6 mg P_2O_5 per 100 g of soil, that is, about 100 kg per ha of residual phosphates accumulated in the arable layer of soil, which in the most critical years after the collapse of the Soviet Union, they largely supported the effective fertility of soils.

The maximum amount of residual phosphates from fertilizers at the end of the fifth round of agrochemical surveys (the weighted average content of P_2O_5, mg per 100 g of soil increased from 6.3 to 11.8 mg, or almost two times) in Polissya, which is explained by the use of higher doses Organic and mineral fertilizers in comparison with other natural zones, as well as a light granulometric composition of soils that have a significantly lower absorbing capacity for phosphorus. To a large extent, the transformation of fertilizer phosphates to sparingly soluble forms decreased due to the systematic liming of acidic soils, which reduced the formation of sparingly soluble aluminum and iron phosphates.

Calculations (according to statistical data) showed that for the period from 1966 to 2014 (that is, for 48 calendar years) about 1410 kg of P_2O_5 per each hectare of arable land has been applied with mineral and organic fertilizers on a total area of 32 million hectares. Thus, in agriculture of Ukraine, on average, about 29 kg of the active substance of phosphorus fertilizers (P_2O_5) annually input to each hectare of arable land. During this period (48 years), taking into account crops, 41 kg of P_2O_5 from each hectare of arable land was output. The overall balance of phosphorus (on average for 48 years) in agriculture was uneven: for 20 years of intensive chemicalization (1971-1992) it was positive, and in 1991-2013 with a sharp decrease in the volume of mineral and organic fertilizers application, a deficit of nutrients, especially phosphorus, increased. For this was greatly facilitated by the implementation of intensive technologies, as well as the changing the soil-depleting structure of crop rotations due to the sharp increase in the areas of sunflower, maize, rapeseed and other crops whose products are exported and provides high income for agricultural holdings.

The implementation of high-intensive technologies with the use of high-potential varieties and the widespread use of chemical agents for controlling weeds and plant diseases led to the production of high yields of maize (up to 8.0 t per ha), sunflower (1,5-2.0 t per ha), winter wheat (4.0-5.0 t per ha) in chernozems of the forest-steppe and steppe zones. Against the background of high potential fertility of chernozems, as well as the use of residual phosphate fertilizer stocks (about 100 kg P_2O_5 per ha), the maximum yields of these crops are mainly due to the use of nitrogen fertilizers. For 2006-2010, mineral fertilizers for winter wheat were applied in the ratio N:P_2O_5 - 1: 0.17 (63.4 and 10.7 kg active ingredient per hectare), for grain corn - 1:0.21 (75.6 and 15.6 kg per ha), for sugar beet - 1:0.42 (152.8 and 64.3 kg per ha) [4]. The application of such a system of fertilization of the main field crops, which occupy the prevailing areas in the structure of crops, caused a transformation from a positive balance of phosphorus in agriculture to a negative one (Figure 3).

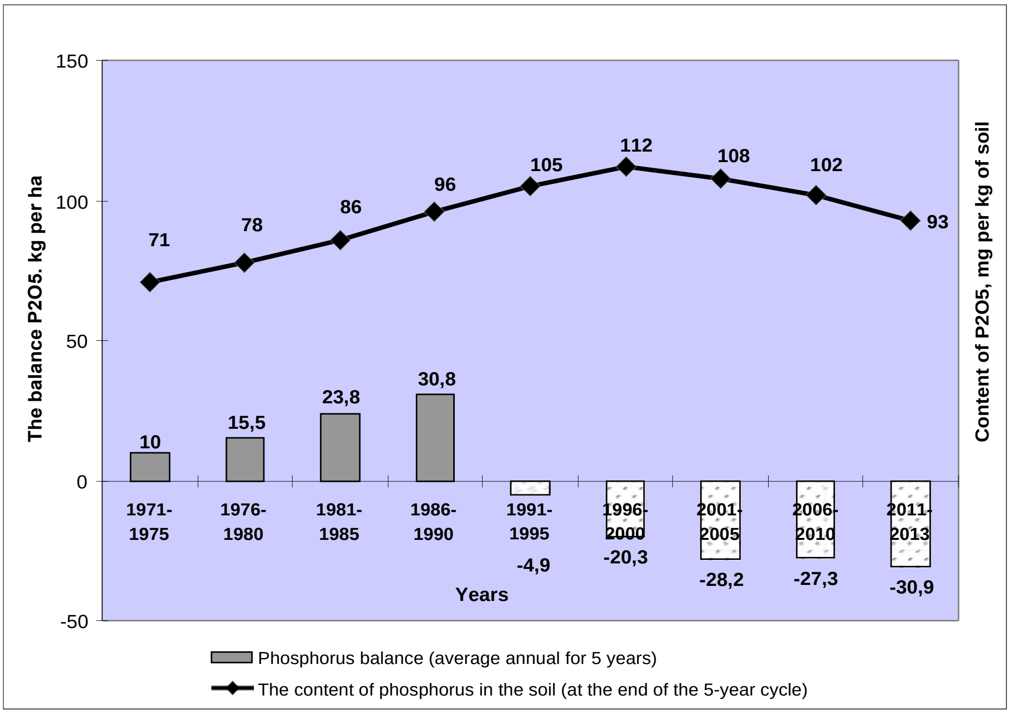

Fig. 3 - Dynamics of the total balance of phosphorus and the weighted average content of P_2O_5 in soils in agriculture in Ukraine

Despite the fact that, with the implementation of modern technologies for harvesting crops (especially corn for grain and sunflower), the input of phosphorus with sifted residues is taken into account in the balance for 2001-2013.

The dynamics of the change in the content of mobile phosphorus is most clearly recorded in the Polissya zone in connection with the genetic characteristics of soils (sandy and clayey-sandy varieties predominate), and with high rates of mineral and organic fertilizers during the period 1971-1990 with simultaneous liming. The actual stopping of liming after 1990, a sharp decrease in the volume of application of organic and mineral fertilizers contributed to a significant decrease in the content of mobile forms of phosphates in soils.

At the same time, it is necessary to bear in mind that mineral fertilizers, in connection with their final economic efficiency, are application in doses that significantly difference depending on the biological characteristics of each crop. This causes a significant difference in the accumulation of residual phosphates in individual fields. In addition, cultural plants, according to Pryanishnikov [14], used for nutrition the phosphorus from soil reserves and fertilizers equally.

Contributes the optimization of the ratio in nitrogen and phosphorus soils for improve the efficiency of soil phosphorus utilization (especially residual phosphate fertilizers).

Conclusions.

1. It was found that for 6 crop rotation, despite the negative balance of phosphorus (734 kg per ha), the content of its mobile forms in the arable layer of soil is kept within 5.5-4.2 mg of P_2O_5 per 100 g of soil. Application phosphorus fertilizers to the stock at a dose of 1,800 kg per ha contributes to the formation of residual phosphates, which retain their mobility and can be a source of phosphate nutrition for the next 30 years, provides a long aftereffect of fertilizers.

2. The results of long-term monitoring in the system of the state agrochemical service testify that the annual excess of phosphorus input with fertilizers relative to its output with yields throughout the country in 1986-1990 was more than 21.0 kg per ha, but today, on the contrary, 27 1 kg per ha of phosphorus is applied less than is output with crop production.

3. Calculation of the total balance of phosphorus and P2O5 content in soils in the agriculture of Ukraine indicates a negative effect of modern management on the phosphate level of soils, and the formation of crops is due to residual phosphates and partly mineralization of humic compounds.

Bibliography.

1. Agro-chemical service in the system of factors of preservation and increase of soil fertility (to the 50th anniversary of the foundation of the Agrochemical Service of Ukraine) scientific report [S.A. Baliuk, B.S. Nosco, A.S. Zarishnyak, M.V. Lisovoj]; In common. Ed. Acad. NAAN S.A. Baliuk - M ., 2015. - 64 p.

2. Guidebook on agrochemical and agroecological state of soils of Ukraine / Ed. B.S. Nosko, B.S. Pristor, M.V. Loboda. -K .: Urogaj, 1994. - 330 p.

3. Egorov M.A. On the question of the balance of phosphorus in crop rotation / Sat. VIUA: Fertilizers in crop rotation. Issue. 11. - M .: Sel'khozhiz, 1963.

4. Zarishnyak A.S., Baliuk S.A., Lisovoj M.V., Komaristja A.V. Balance of

humus and nutrients in soils of Ukraine // Bulletin of Agrarian Science. - 2012. № 1. - P.28-32.

5. Kudeyarova A.Yu. Pedogeochemistry of poly- and orthophosphates under conditions of application of fertilizers. Moscow: Nauka, 1993. - 240 p.

6. Kudzin Yu.K. Nutrition conditions and productivity of agricultural plants with long-term use of fertilizers on chernozem soils Forest-steppe of the USSR // Abstract. Diss. Doctor of agrarian sciences. - Voronezh: Ministry of Agriculture of the RSFSR, 1962. -47 p.

7. Kulakovskaya T.N. Soil-agrochemical basis for obtaining high yields. – Minsk, 1978. - 230 p.

8. Nosco B.S. Phosphate soil regime and fertilizer efficiency. K.: Urogaj, 1990. - 220 p.

9. Nosco B.S. Anthropogenic evolution of chernozems. - Kharkiv: "Printing house number 13", 2006. - 240 p.

10. Nosko B.S. Use of the method of background modeling in the study of agrochemical properties of soils // Agrochemistry. 1981. No. 1. - P. 122-127.

11. Nosko B.S., Hladkikh Ye.Yu. To the problem of the transformation and duration of the aftereffects of phosphate fertilizers in chernozems // Bulletin of Agrarian Science. - 2012. No. 5. - P. 11-15.

12. Nosko B.S., Babynin V.I., Hladkikh Ye.Yu. Aftereffect of fertilizers on physicochemical and agrochemical properties of typical chernozem // Agrochemistry. 2012. – № 4. - P. 3-13.

13. Polupan M.I., Velichko V.A. Nomenclature and diagnostics of ecological and genetic status of Ukraine soils for their large-scale research. - Kiev.: Agrarian Science, 2014. -494 p.

14. Pryanishnikov D.N. Selected works. - T. 3. - Moscow, 1952. - 633 p.