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THE INFLUENCE OF FERTILIZER SYSTEM IN THE FIELD CROP ROTATION ON CERTAIN PHYSICAL AND CHEMICAL PROPERTIES OF PODZOLIZED BLACK SOIL

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The experimental data about changes of indices of hydrolytic and exchange acidity, amount of absorbed bases, absorption capacity and the degree of saturation of the soil with bases after 45 years of growing crops in crop rotation without fertilizer and with different fertilization systems are observed.

Keywords: *fertilization system, acidity, amount of absorbed bases, absorption capacity, degree of saturation with bases.*

One of the major problems of agriculture at the present stage is to ensure stabilization of soil fertility, prevent their degradation, and in the future – to improve soil fertility and productivity.

Adding a sufficient number of organic and mineral fertilizers improves soil fertility. Fertilizers significantly affect the physical, chemical and agrochemical soil properties. In turn, those properties affect the soil nutrient regime, its biological activity and interaction of fertilizers with soil and plants, and cause the yield and quality of agricultural products.

Physical-chemical properties of soil are characterized by actual, exchange and hydrolytic acidity, cation absorption capacity, the amount of absorbed bases, composition of exchange cation, degree of saturation of soil with bases [1]. As the corresponding member of NAAS of Ukraine A.S. Zarishnyak points out [2] that one of the most important indicators of soil fertility increase or soil degradation in the rotation is determination of the physical and chemical properties under the influence of fertilizers. Effect of fertilizer, especially mineral on the physical-chemical, microbiological and other regimes of soil is happened due to the fact that fertilizers consist of chemical salts, which in most cases are soluble in water and decompose into cations and anions. The most strongly on the soil, in particular on its absorbing complex (SAC) impact monovalent cations of potassium, sodium, ammonium [3].

Studying of physical and chemical properties of soil in the system soil – plant – fertilizer for the development and implementation of measures directed to improve its fertility and crop yields, will promote efficient use of fertilizers and other chemicals. In this regard, the research results obtained in stationary experiments with prolonged use of fertilizers are of special value.

The objective of our research, the results of which are presented in this article was to find out how are changed the indices of hydrolytic and exchange acidity, amount of absorbed bases, absorption capacity and the degree of podzolized heavy loamy black soil saturation with bases for long-term (45 years) use of organic, mineral and organic-mineral systems of fertilizing in the field crop rotation compared with soil without fertilizer.

Research methodology. The study was conducted in continued stationary research of Agricultural Chemistry and Soil Science Department of Uman National University of Horticulture. The research laid in 1964 on the podzolized black soil. In the year of the research laying, humus content in the soil layers 0 - 20 and 20 - 40 cm was respectively 3.31 and 3.00%. Mobile forms of phosphorus by Truog and exchangeable potassium by Brovkina in the layer 0 - 20 cm were respectively 13 and 10 mg/100g of soil. Indices of exchange, hydrolytic acidity and amount of absorbed bases in the period of the research are presented in Table 1-3.

Crops alternation in crop rotation is as follows: perennial grass on a slope – winter wheat – sugar beet – maize for grain – pea – winter wheat – maize for silage – winter wheat – sugar beet – barley with sowing of herbs.

Fertilizers applied: half-rotted manure, ammonium nitrate, pelleted superphosphate and potassium salt.

Determination of physical-chemical parameters of soil was conducted in 2008 and 2009 in a field under barley in variants: without fertilizer (control), using organic (9 t / ha of crop rotation area of manure), mineral ($N_{45}P_{45}K_{45}$) and organic-mineral (4, 5 t / ha of manure + $N_{22,5}P_{33,8}K_{18}$) fertilization systems in crop rotation.

Exchange acidity (salt extraction pH) defined by the displacement of exchange ion H^{+} i Al^{3+} 1-н from soil with the help of dissolvent KCl at a ratio of soil to solution 1:2,5 followed by measuring the activity of hydrogen ions by potentiometric method. Hydrolytic acidity determined by the method of Kappen, the amount of absorbed bases – by Kappen-Hilkovytsya method [1]. Based on indices of hydrolytic acidity and amount of absorbed bases, calculations of absorption capacity and the degree of saturation of the soil with bases was made.

Results of the investigation. Research program intended to find out how the reaction of the soil changed under the influence of long-term use of different fertilization systems in the crop rotation. The reaction of the soil has a great influence on the growth and development of plants, microbiological, chemical and biochemical processes of the soil. Absorption of nutrients of soil and fertilizers by plants, mineralization of organic substance, efficiency of added fertilizers, yield of crops and their quality depend on the reaction of the soil. Acid reaction has a negative impact on soil and plants. However, in Ukraine, as Academician V. Sayko points out[4], every fourth hectare of soil is asidic, and in the Forest-Steppe zone, Polissya – every second (49,7 – 47,4%). Large areas of acid soils are in the Cherkassy region.

Exchange acidity of the soil caused by the exchange-absorbed hydrogen ions and aluminum, which can be displaced from the soil by cations of neutral salts. Soils that have high exchange acidity, are characterized by particularly unfavorable properties. Very harmful is acidity caused by the exchange aluminum, which is toxic for most plants. With an excess of hydrogen and aluminum, delays the root development, reduces the number of root hairs, reduces an active surface of roots, deteriorates supply of plants with nutrients.

Results of determination of exchange acidity in the soil show that during 45 years exchange acidity was gradually increasing in the soil as in crop rotation both without fertilizer and with all systems of fertilization (Table 1). The largest increase of exchange acidity occurred in soil of crop rotation without fertilization and in crop rotation with mineral fertilization system. In the soil layer 0 - 60 cm index pH of salt extraction on the control decreased, compared to 1964 by 1,09 units, and in the variant with mineral fertilizer system by one unit. In crop rotation with organic fertilizer system the reduction was 0,75, and with the organic-mineral – 0,73 units. In crop rotation without fertilization in 2008 – 2009 acidity of top 20-cm soil layer was higher than in the layers 20 – 40 and 40 – 60 cm, but the rate of increase of acidity versus 1964 in the top layer is somewhat slower. In all variants with fertilization, index $pH_{(KCl)}$ was higher against the control, soil acidity in these variants was lower than on control.

1. Exchange acidity of soil, $pH_{(KCl)}$, in crop rotation with prolonged use of different fertilizer systems

Fertilizer system in crop rotation	Soil layer, cm	1964	Average for 2008 – 2010	± before	
				1964	control
Without fertilization (control)	0 – 20	6,20	5,25	– 0,95	–
	20 – 40	6,50	5,45	– 1,05	–
	40 – 60	6,80	5,55	– 1,25	–
	0 – 60	6,50	5,41	– 1,09	–
Mineral ($N_{45}P_{45}K_{45}$)	0 – 20	6,20	5,80	– 0,40	+ 0,55
	20 – 40	6,50	5,65	– 0,85	+ 0,20
	40 – 60	6,80	5,80	– 1,00	+ 0,25
	0 – 60	6,50	5,75	– 0,75	+ 0,34
Organic (manure 9 t/ha)	0 – 20	6,20	5,25	– 0,95	0,00
	20 – 40	6,50	5,55	– 0,95	+ 0,10
	40 – 60	6,80	5,70	– 1,10	+ 0,15
	0 – 60	6,50	5,50	– 1,00	+ 0,09
Organic-mineral (manure 4,5 t/ha + $N_{22,5}P_{33,8}K_{18}$)	0 – 20	6,20	5,70	– 0,50	+ 0,45
	20 – 40	6,50	5,65	– 0,85	+ 0,20
	40 – 60	6,80	5,95	– 0,85	+ 0,40
	0 – 60	6,50	5,77	– 0,73	+ 0,36

With the help of exchange acidity index determines the need of soil in liming. In our permanent study area podzolized black soil during the experiment didn't need liming because pH was 6,2 in the top layer, and in the layer 0 – 60 cm – 6,5, in other words, by the degree of acidity the soil belonged to neutral. If the $pH_{(KCl)}$ is in the range of 5,1 – 5,5, these soils are slightly acidic. After 45 years of use, the soil in crop rotation without the use of fertilizers moved in this group, where $pH_{(KCl)}$ was in the layer 0 – 20 cm – 5,25 and in the layer 0 – 60 cm – 5,41, and also with the use of mineral system of fertilization, where the index in the layer of 0 – 20 cm was 5,25 and in the layer 0 – 60 cm – 5,50. The need of liming of this soil is medium. In crop rotation with organic and organic-mineral fertilizer systems, the soil is close to neutral due to the degree of acidity and the need of liming is small.

Similar salt pH indices are obtained in variants using organic and organic-mineral fertilizers in experiments of Veselopodilska Research and Breeding Station of Sugar beet Institute of NAAS on weakly alkaline black soil with low humus content [2].

Hydrolytic acidity is predetermined by less moving hydrogen ions, which are more difficult to replace with soil solution cations than those characterizing the exchange acidity. This type of acidity is determined by the interaction of soil with hydrolytically alkaline salt solution CH_3COONa. During the action of alkaline solution on the soil complex, are displaced also those hydrogen ions H^+, which tightly bound to soil complex, therefore their amount is bigger than during the effect on the soil of neutral salt.

Hydrolytic acidity is common or complete, as it includes all potential and actual acidity [1]. With the help of hydrolytic acidity, the norm of lime for liming acid soils determines.

In our experiment is observed a significant increase of hydrolytic acidity of the soil both without using fertilizers in crop rotation and with application of all fertilizer systems (Table 2).

2. Hydrolytic soil acidity (Hs) in crop rotation with prolonged use of different fertilizer systems, resin/kg of soil

Fertilizer system in crop rotation	Soil layer, cm	1964	Average for 2008 – 2010	± before	
				1964р.	control
Without fertilization (control)	0 – 20	1,90	3,95	+2,05	–
	20 – 40	1,70	3,30	+1,60	–
	40 – 60	1,50	2,55	+1,05	–
	0 – 60	1,70	3,25	+1,55	–
Mineral ($N_{45}P_{45}K_{45}$)	0 – 20	1,90	2,75	+0,85	–1,20
	20 – 40	1,70	2,70	+1,00	–0,60
	40 – 60	1,50	2,55	+1,05	0,00
	0 – 60	1,70	2,65	+0,95	–0,60
Organic (manure 9 t/ha)	0 – 20	1,90	4,20	+2,30	+0,25
	20 – 40	1,70	3,90	+2,20	+0,60
	40 – 60	1,50	3,10	+1,60	+0,55
	0 – 60	1,70	3,75	+2,05	+0,50
Organic-mineral (manure 4,5 t/ha + $N_{22,5}P_{33,8}K_{18}$)	0 – 20	1,90	3,40	+1,50	–0,55
	20 – 40	1,70	3,20	+1,50	–0,10
	40 – 60	1,50	2,20	+0,70	–0,35
	0 – 60	1,70	2,90	+1,20	–0,35

During the experiment (45 years) hydrolytic acidity of the soil in the crop rotation without the use of fertilizers in the layer 0 – 20 cm increased to 2,05 Resin / kg. Using mineral fertilizer system, the largest increase of hydrolytic acidity is observed – from 1,9 to 4,2 kg of resin on the kg of soil. In this variant, the largest increase of acidity is observed in the whole 60-cm layer – to 2.0 Resin / kg of soil. The smallest increase of acidity was in soil of crop rotation with organic fertilizer system. Characteristically, that using this system and organic-mineral system, level of hydrolytic acidity was lower than on the control.

Considering hydrolytic acidity in the top layer of soil from 3,1 to 4,0 Resin / kg soils are acidic, and in Forest-Steppe zone they have a medium need of liming [5]. To this group now belongs the studied soil in crop rotation with mineral, organic-mineral fertilizer systems and without fertilization.

In crop rotation with organic fertilizer system with level of hydrolytic acidity 2,75 Resin / kg, liming is appropriate for growing cultures which are sensitive to acidic reaction of soil.

So, during prolonged cultivation of crops using mineral and organic-mineral fertilization systems in crop rotation, and without fertilization, soil faster needs liming and in bigger norms, than in the crop rotation with organic fertilization system.

It's typical for each soil type to have certain cations. In the black soils, which include the soil under experiment, in absorbing complex dominate cations Ca^{2+} and Mg^{2+}. These cations promote the formation of lump-grained soil structure, which improves its agrophysical properties.

Composition of absorbed cations is characterized by indicators of the amount of absorbed bases and degree of soil saturation with bases. Amount of absorbed bases – is the total number of all cations of bases of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH^{+}, absorbed by fine dispersed part of soil and capable to exchange. These cations play an important role as a direct source of nutrients for plants. They are not washed out of the soil and at the same time are relatively easy forced out into solution and they are well absorbed by plants.

Prolonged cultivation of crops without fertilizer reduces the amount of absorbed bases in soil. In our experiment in 2009, the amount of absorbed bases in the soil layer 0 – 20 cm was on 26,2% less compared with this index in 1964 (Table 3). In the deeper layers, the reduction of the amount of absorbed bases is also occurred, but to a lesser extent than in the top layer. In layer 0 – 60 cm the content of cation of bases decreased to 20,5 percent. This decrease is due to the good absorption of cations of bases by the plants during their nutrition.

Typical that none of the studied systems did not provide compensation of expended amount of absorbed bases from the soil. Thus, in the 60-cm layer of soil in the crop rotation with organic fertilizer system (manure, 9 t / ha) the amount of absorbed bases during the 45-years period of crops cultivation decreased to 20,3%, with mineral ($N_{45}P_{45}K_{45}$) – 16,2 and with organic-mineral (manure 4.5 t / ha + $N_{22,5}P_{33,8}K_{18}$) – to 14,7%.

In the 40-years experiment of V. Nemchenko on weakly alkaline black soil with low humus content, the amount of absorbed bases decreased from 27 to 21,8 mg/eqv/100 g of soil. Indicators were independent of the background of fertilizer and precursor [6].

In this manner, the use of mineral and organic-mineral fertilizer systems with saturation of nutrients at the level of 135 kg /gata organic with saturation of 121.5 kg / ha (manure 9 t / ha), does not provide the stabilization of indicator of the absorbed bases amount on the initial level.

Absorbing capacity of the soil is characterized by the absorption volume, in other words the number of cations which soil could hold. On soils with high absorption volume, which is typical for black soils, there is relatively slight leaching of nutrients after fertilization. On soils with low absorption volume, sparingly soluble fertilizers could leach into the lower layers of the soil and could be lost.

We determined the capacity of absorption (T) by summing indicators of hydrolytic acidity (Nh) and the amount of absorbed bases (S). According to the data of Table 4, the absorption capacity of soil in 45 years decreased on control in the layer 0 – 20 cm to 18% in the layer 0 – 60 cm – to 14.1%. Absorption capacity in the soil with organic fertilizer system decreased to 17 and 16% respectively. In the soil of crop rotation with mineral and organic-mineral fertilizer systems, reduce of absorption capacity was also observed, but to a much lesser extent. Therefore using mineral fertilizer system, capacity of absorption in the layer 0 – 60 cm decreased to 8,7, and the organic-mineral – to 9,9%. This is obviously due to the fact that with the fertilizers the soil received a significant amount of cations of bases, which compensated some of their losses.

3. Changes of indicator of the absorbed bases amount depending on the prolonged use of different fertilizer systems in crop rotation, Resin/kg of soil

Fertilizer system in crop rotation	Soil layer, cm	1964	Average for 2008 – 2010	±before	
				1964	control
Without fertilization (control)	0 – 20	29,00	21,40	–7,60	–
	20 – 40	29,10	23,10	–6,00	–
	40 – 60	29,80	25,60	–4,20	–
	0 – 60	29,30	23,36	–5,94	–
Mineral ($N_{45}P_{45}K_{45}$)	0 – 20	29,00	22,90	–6,10	+1,50
	20 – 40	29,10	23,00	–6,10	–0,10
	40 – 60	29,80	24,20	–5,60	–1,40
	0 – 60	29,30	23,36	–5,94	0,00
Organic (manure 9 t/ha)	0 – 20	29,00	24,10	–4,90	+2,70
	20 – 40	29,10	24,40	–4,70	+1,30
	40 – 60	29,80	25,20	–4,60	–0,40
	0 – 60	29,30	24,56	–4,74	+1,20
Organic-mineral (manure 4,5 t/ha + $N_{22,5}P_{33,8}K_{18}$)	0 – 20	29,00	24,60	–4,40	+3,20
	20 – 40	29,10	25,30	–3,80	+2,20
	40 – 60	29,80	25,10	–4,70	–0,50
	0 – 60	29,30	25,00	–4,30	+1,64

For agronomic evaluation of soil, it is important to consider the degree of its saturation with bases, in other words to know the share in the total capacity of absorption, which is for absorbed bases. It is expressed in a percentage. In the agronomic meaning, the most favorable soil is considered the soil with degree of base saturation of 90 percent or more. This soil generally has sufficient reserves of nutrients, close to neutral reaction, and it’s characterized by high effective fertility.

Calculations of this indicator in the soil during the experiment showed that the researched systems of fertilization failed to stabilize it at the initial level. The greatest decrease of this indicator compared to the level in 1964 was occurred in the soil of crop rotation without fertilization and with mineral system. At the beginning of the experiment the degree of base saturation in the soil was on the level of 93 – 95%. In 2008 – 2009, this indicator in the layer 0 – 60 cm ranged from 86,7 – 89,7%, which was lower than 90%.

Conclusions. 1. Growing of agricultural crops in crop rotation within 45 years leads to a gradual increase of soil acidity versus output level both without the use of fertilizers and with use of organic, mineral and organic-mineral fertilizer systems.

Herewith somewhat slower passes acidification of soil with organic and organic-mineral systems.

4. Soil absorption capacity (T), degree of base saturation (V) depending on the prolonged use of different fertilizer systems in crop rotation

Fertilizer system in crop rotation	Soil layer, cm	T, Resin/kg of soil			V, %		
		1964	Average for 2008 – 2010	±before 1964	1964	Average for 2008 – 2010	± before 1964
Without fertilization (control)	0 – 20	30,9	25,35	–5,55	93,85	84,41	–9,44
	20 – 40	30,8	26,40	–4,40	94,48	87,50	–6,98
	40 – 60	31,3	28,15	–3,15	95,20	90,94	–4,26
	0 – 60	31,0	26,63	–4,37	94,51	87,72	–6,79
Mineral ($N_{45}P_{45}K_{45}$)	0 – 20	30,9	25,65	–5,25	93,85	89,27	–4,58
	20 – 40	30,8	25,70	–5,10	94,48	89,49	–4,99
	40 – 60	31,3	26,75	–4,55	95,20	90,46	–4,74
	0 – 60	31,0	26,03	–4,97	94,51	89,74	–4,77
Organic (manure 9 t/ha)	0 – 20	30,9	28,30	–2,60	93,85	85,15	–8,70
	20 – 40	30,8	28,30	–2,50	94,48	86,21	–8,27
	40 – 60	31,3	28,30	–3,00	95,20	89,04	–6,16
	0 – 60	31,0	28,30	–2,70	94,51	86,78	–7,73
Organic-mineral (manure, 4,5t/ha+$N_{22,5}P_{33,8}K_{18}$)	0 – 20	30,9	28,00	–2,90	93,85	87,85	–6,00
	20 – 40	30,8	28,50	–2,30	94,48	88,77	–5,71
	40 – 60	31,3	27,30	–4,00	95,20	91,94	–3,26
	0 – 60	31,0	27,93	3,07	94,51	89,50	–5,01

2. Amount of absorbed bases for the years of experiment in the crop rotation without fertilization in the layer 0 – 60 cm decreased to 20,5% compared to output level. None of the studied systems of fertilization failed to compensate expended from the soil cations of bases. In organic system, these losses were the same as in the crop rotation without fertilization, somewhat less was observed in the crop rotation with mineral and organic-mineral fertilizer systems (16,2 and 14,7%).

3. Absorption capacity of soil in layer 0 – 60 cm decreased to 14,1% in crop rotation without fertilization and to 16% using the organic system. In the soil of crop rotation with mineral and organic-mineral systems reducing was observed to 8,7 and 9,9% versus initial level.

4. Prolonged cultivation of crops in crop rotation without fertilization and with different fertilization systems does not provide the stabilization of certain physical and chemical properties of podzolized black soil at initial level, it deteriorates them.

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