UDC:631:147

AGROGENESIS OF REGRADED CHERNOZEM AND THE PERFORMANCE OF GRAIN CROPS UNDER ORGANIC SYSTEM OF FERTILIZATION

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Received on October 10, 2017

Aim. To conduct complex agrophysical, physical-chemical substantiation of the efficiency of the organic fertilization system in terms of nitrogen balance and organic carbon in the agroecosystem of a five-field grain-growing and weeding crop rotation filled with cereals and legumes up to 40 % and the use of by-products for fertility restoration and improvement of the agrogenesis of regraded chernozem in the central part of the Forest-Steppe of Ukraine. **Methods.** Laboratory-analytical, experimental field, computational, statistical. **Results.** The systematic application of the organic system of fertilization in a short grain-growing and weeding crop rotation with the use of by-products as organic fertilizers promotes the increase in the points of exchange neutrality and the decrease in the unsaturation of regraded chernozem with the alkali of the tilled layer, while the increase in microaggregation and structure-building is conditioned by the approximation of potential acidity to the isoelectric state of soil colloids which is a feature of the process of biologization and simulation of natural soil formation in agroecosystems of the central part of the Forest-Steppe of Ukraine. Under the organic fertilization system the decrease in the agroecosystem performance is related to the decrease in the volume of nitrogen balance which testifies to the decrease in the intensity of its circulation in agroecosystem: the processes of enhancing the humification of by-products and the formation of prohumus substances prevail, accompanied with the intensification of atmospheric CO_2 involvement in the formation of the total phytomass of the harvest, and the agroecosystem transforms into a stock system, which may be characterized as a basic system for organic production of plant cultivation. **Conclusions.** The elaborated system of organic fertilization of crops in a five-field grain-growing and weeding crop rotation allows avoiding the use of organic fertilizers and perennial grasses and using by-products of plant cultivation instead to saturate the crop rotation with legumes up to 30–40 %, the application of nitrogen-fixing and phosphate-mobilizing preparations allows ensuring the production of organically pure products with simultaneous restoration of both fertility and the natural model of the chernozem agrogenesis of the central part of the Forest-Steppe of Ukraine.

Keywords: microaggregates, structure density, humus, balance, organic carbon, crop rotation, by-products, fodder and grain protein units.

DOI: 10.15407/agrisp4.03.050

INTRODUCTION

The relevance of biological (organic) agriculture in the conditions of a stable tendency to the climate change which has been rather sharp in the recent decade in the territory of the central part of the Forest-Steppe of Ukraine, conditioned both by global processes and current industrial processes, aimed at fighting the consequences rather than preventing their negative manifestation, is rather evident [1]. The idea of organic agriculture has emerged as a natural and adequate reaction of agricultural production on rapid and active increase in chemical pressing on the agriculture [2]. The concept of organic production proves that it is much more complicated to achieve the main aim than to maintain formal conditions, required for certification of the production of organic products, as the certification does not guarantee any harmonization and does not regulate the anthropogenic burden on agroecosystems in general [3]. The main point is to provide the necessary conditions of plant nutrition along with restoration of chernozem fertility, which is rather complicated in the absence of animal breeding and seeding perennial grasses, that is related to the complexity of maintaining the positive balance of humus, nitrogen and phosphorus. However, there is an urgent issue of elaborating such technological means of organic production which would allow using the by-products and the saturation of crop rotations with legumes up to 30–40 % to ensure obtaining of organically pure products with simultaneous restoration of fertility and, as a result, to provide for the restoration of the natural model of agrogenesis of chernozems in the central part of the Forest-Steppe of Ukraine [4].

In general, the Forest-Steppe zone is ranked second in Ukraine by the level of anthropogenic burden on natural ecosystems [5]. The diversity of soil and ecological conditions is the reason for the versatility of lands by their productive capability and hence – for different agronomic suitability for organic agriculture. Therefore, a structure of soil cover, whose components are characterized by specific parameters of suitability at the level of their kinds, is used to zone Ukraine by the suitability for organic agriculture. The territory of studies may be related to the group of lands, suitable for organic agriculture, where high medium-perennial productive capability of soils is ensured (70–100 points depending on the agricultural crop).

The aim of the studies was to conduct complex agrophysical, physical-chemical substantiation of the efficiency of the organic fertilization system in terms of nitrogen balance and organic carbon in the agroecosystem of a five-field grain-growing and weeding crop rotation filled with cereals and legumes up to 40 % and the use of by-products for fertility restoration and improvement of the agrogenesis of regraded chernozem in the central part of the Forest-Steppe of Ukraine.

MATERIALS AND METHODS

The studies were conducted in the field permanent experiment of the Cherkasy State Agricultural Experimental Station of the National Scientific Center "Institute of Agriculture", NAAS of Ukraine, established in 2010. The soil was regraded chernozem (podzolic chernozem) [6], which was low-humus, medium-clay on carbonate mole-plowing forest layer. The content of humus in the arable layer was 2.76–3.03 according to Turin, the amount of absorbed alkali – 24.5–28.1 mg-eq. per 100 g of soil, the hydrolytic acidity – 1.99–2.19 mg-eq./100 g of soil, pH of the salt extract – 5.56–6.31. The degree of saturation with alkali was 92.8–93.3 %, the content of mobile forms of phosphorus (according to Truog) – 9 mg per 100 g of soil, exchange potassium (according to Brovkina) – 12 mg per 100 g of soil. The physical features of soil are characterized by the following indices: relative weight of solid phase – 2.57–2.62 g/cc, structure density – 1.24–1.30 g/cc, total cleavability of humus horizon – 50–53 % [7].

The experiment studied the five-field grain-growing and weeding crop rotation consisting of peas – winter wheat – corn – soy – spring barley. The main requirement to the organic crop rotation was its saturation with legumes of over 30 %. The saturation of the presented crop rotation with legumes was 40 %.

The organic system of fertilization: without the introduction of mineral fertilizers and the use of by-products of the predecessor as a fertilizer – 13–14 t/ha, and 24–25 t/ha considering the root mass. The intense system of fertilization: green peas – $N_{30}P_{30}K_{30}$, winter wheat – $N_{60}P_{60}K_{60}$ + N_{30}, soy – $N_{60}P_{60}K_{60,}$ corn – $N_{60}P_{70}K_{60}$ + N_{20}, spring barley – $N_{60}P_{60}K_{60}$ + N_{25} at the introduction of 14–15 t/ha of by-products as organic fertilizers, and 26–27 t/ha considering the root mass. The grain for seeding was treated with nitrogen-fixing, phosphorus-mobilizing biological preparations for variants of the experiment.

To determine the changes in physical, chemical, and agrophysical indices while studying the humus and agrophysical conditions, mixed samples were selected 10 cm apart from different land plots following the schemes of experiments according to DSTU 7030:2009 (GSTU 46.001-96). The granulometric composition was defined according to N. A. Kachynsky (DSTU 4730:2007), the structure density – by the method of cutting rings in the modification of N.A. Kachynsky (DSTU ISO 11272:2001); the structural-aggregate composition – by the sieve method in the modification of N.I. Savinov (DSTU 4744:2007), pH_{KCl} – by the potentiometric method (DSTU ISO 10390:2007); the hydrolytic acidity – according to G. Kappen in the modification of CINAO (GOST 26212-91); the total of absorbed alkali – by the method of Kappen-Hilkovits (GOST 27821-88). The content of total humus was determined according to I.V. Turin in the modification of M.V. Simakov (DSTU 4289:2004). The calculation method was used to determine: dispersion factor (DF) according to N.A. Kachynsky; the degree of aggregation (Ka) according to Baver. The results of field studies were statistically processed by the dispersion analysis method using statistical programs of Statistica-8.

RESULTS OF INVESTIGATIONS

The combined studies of granulometric and microaggregate composition allows defining the potential capability of chernozem to structuring under the impact of different systems of fertilization. It was determined that the least level of dispersion was in the variant where soil was used for fallow; it was 7.01 % in the soil layer of 0–20 cm, and 5.6 % – in the 30–40 cm layer, which is characterized as excellent microaggregation of soil mass of chernozem. Out of tilled soils, the soil, which was better microaggregated by the dispersion factor (F_D), was in the variant with the application of the organic system of fertilization, amounting to 7.3 and 7.1 % by soil layers, respectively (Table 1).

The application of the intense system of fertilization, using mineral fertilizers mainly, was less favorable for the maintenance of microaggregates of regraded chernozem. For instance, F_D in the upper 10–20 cm layer was 13.4, and in the lower 30–40 cm layer – 10 (Table 1). In case of the organic system of fertilization, 92.7 % of silt was involved into microaggregates, the fraction of fine dust was involved into microaggregates for 76.7 %, the fraction of medium-sized dust – only for 44.7 % (Fig. 1).

Under the intense system of fertilization, the silt was involved for 86.6 %, fine and medium-sized dust – for 76.3–54.1 % respectively. Many years of using regraded chernozem as fallow promoted the improvement of aggregation of different mechanic elements into structural units, here the silt fraction was involved for 93 %, fine dust – for 87.1 %, medium-sized dust – for 65.8 %. The results of analyses of the lower (30–40 cm) layer of the humus horizon of regraded chernozem demonstrate the tendency to better microstructuring of tilled soils both under the system of organic fertilization, and the mineral one, especially when fractions of fine and medium-sized dust are involved (Fig. 2). This soil layer was practically not touched by soil-tilling devices, only by root systems instead, so in some respect it is a conserver for fresh involved organic substances and the active action of microorganisms and soil mesofauna, notable for natural lands.

The study of the structural composition of regraded chernozem demonstrated that the application of or-

Table 1. The granulometric and microaggregate composition and potential capability to structuring regraded chernozem under different systems of fertilization in case of their long-term application

The system of fertilization	Soil layer, cm	Fractions, mm and their content, %						Dispersion factor according to N.A. Kachynsky, %	Aggregation degree according to Baver, %
		1.0–0.25 (large grain sand)	0.25–0.05 (fine sand)	0.05–0.01 (large grain dust)	0.01–0.005 (medium size dust)	0.005–0.001 (fine dust)	Under 0.001 (silt)		
*intense	10–20	<u>0.21</u>	<u>19.5</u>	<u>43.7</u>	<u>7.90</u>	<u>11.6</u>	<u>17.1</u>	13.4	53.2
		2.95	39.2	52.0	1.87	1.66	2.29		
	30–40	<u>0.71</u>	<u>22.1</u>	<u>42.0</u>	<u>14.8</u>	<u>7.02</u>	<u>14.6</u>	10.0	49.3
		3.67	41.4	45.7	4.99	2.70	1.46		
organic	10–20	<u>0.21</u>	<u>19.5</u>	<u>43.7</u>	<u>7.90</u>	<u>11.6</u>	<u>17.1*</u>	7.30	56.7
		4.69	40.8	46.2	4.39	2.70	1.25**		
	30–40	<u>0.71</u>	<u>22.1</u>	<u>42.0</u>	<u>14.8</u>	<u>7.02</u>	<u>14.6</u>	7.10	51.2
		3.86	42.9	47.4	3.35	1.43	1.04		
fallow	10–20	<u>0.21</u>	<u>19.5</u>	<u>43.7</u>	<u>7.90</u>	<u>11.6</u>	<u>17.1</u>	7.01	64.7
		5.08	50.8	38.7	2.70	1.50	1.20		
	30–40	<u>0.71</u>	<u>22.1</u>	<u>42.0</u>	<u>14.8</u>	<u>7.02</u>	<u>14.6</u>	5.60	53.2
		10.3	38.5	48.3	1.04	1.04	0.83		

* The data of granulometric analysis; ** the data of microaggregate analysis.

ganic system of fertilization for 7 years had a positive effect on the structural composition. The content of lumpy aggregates with the size, exceeding 10 mm, was 12.7 %, the dispersed fraction under 0.25 cm was at the level of 15.6 %, and the content of agronomically valuable aggregates – 71.7 %. When these fractions were analyzed in finer detail, the highest amount was registered for a so called grain fraction with the size of 5–3 mm – 9.95 %; 3–2 mm – 8.75 % and fine grain fraction of 2–1 mm – 19.5 %. The most valuable fractions in terms of absorption and preservation of soil moisture and size were most resistant to erosion and deflation processes and amounted to the total of 38.2 %.

The application of the intense system with the introduction of mineral fertilizers resulted in the formation of a lumpy fraction – 52 %. The content of the dispersed fraction was considerably small – 4.37 %, thus the content of agronomically valuable aggregates was 43.6 %. The analysis of the content of agronomically valuable fractions demonstrated that larger fractions with the size of 10–7 cm prevailed, amounting to 10.7 %; those of 7–5 cm – 7.09 and 5–3 cm – 9.10 %.

The redistribution of agronomically valuable structural specificities within the range of agronomically valuable interval under different systems of fertilization demonstrates that long-term application of the organic system of fertilization simulates the natural process of soil formation and changes towards the preservation of the fallow (Fig. 3).

The best structuring was noted for the upper 0–20 cm layer of regraded chernozem under perennial fallow. The samples of this soil had practically no fractions over 1 mm. The dispersed fraction under 0.25 mm was 12.9 %, and the content of agronomically valuable aggregates was 86.7 %, estimated as a wonderful structured condition. Here the highest content was noted for grain fractions: 5–3 mm – 14 %; 3–2 mm – 16.8 % and 2–1 mm – 26.3 %.

The estimation of the structural composition of regraded chernozem under different systems of fertilization demonstrates a considerable increase in the content of a lumpy fraction under the intense system of fertilization, though its percentage decreases considerably with depth. As for the organic system of fertilization, with depth the content of dust decreases considerably from 15.6 % in a 0–10 cm layer to 6.67–4.02 % in lower layers of chernozem. The content of agronomically valuable structural specificities under dry seeding according to the scale of P.U. Bakhtin and N.I. Savinov (1966) was good under the organic sys-

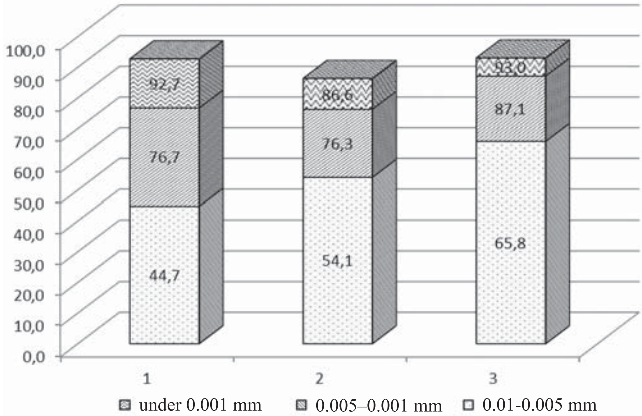

Fig. 1. The degree of involvement (%) of mechanic elements into microaggregates under different systems of fertilization of regraded chernozem in the soil layer of 10–20 cm (1 – organic system; 2 – intense system; 3 – fallow)

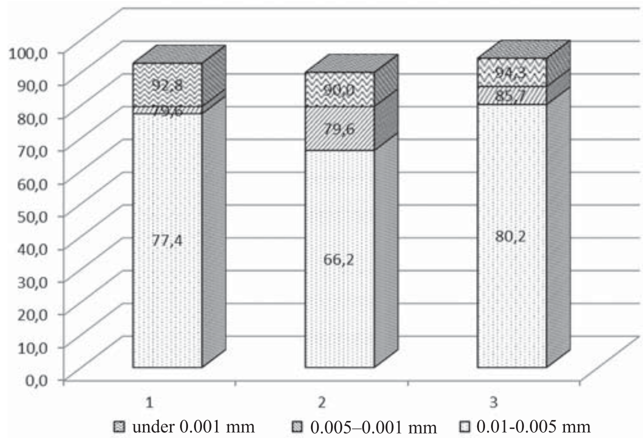

Fig. 2. The degree of involvement of mechanic elements into microaggregates under different systems of fertilization of regraded chernozem in the soil layer of 30–40 cm (1 – organic system; 2 – intense system; 3 – fallow)

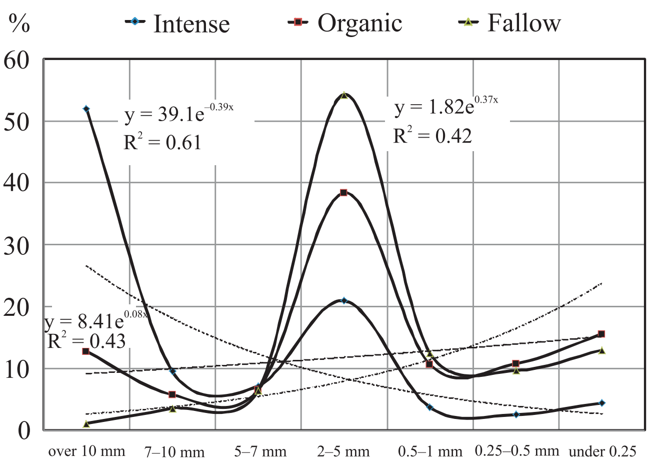

Fig. 3. The long-term impact of different systems of fertilization on the redistribution of structural aggregates in the 0–20 cm layer of regraded chernozem

tem of fertilization: 60–80 %, and under the intense system of fertilization: satisfactory (0–20 cm), and in lower ones (30–40 cm) – good. In the conditions of a fallow, the structuring of chernozem was high in the investigated horizon of chernozem which was in the range of 83.9–89.3 %, characterized as a great status (Table 2).

The investigation of the density of regraded chernozem composition after the application of different systems of fertilization for 7 years demonstrated that its values in the tilled soil layer were not beyond the optimal range and amounted to 1.19–1.21 g/cc for the organic system of fertilization, and under the intense system of fertilization the density range was wider – 1.18–1.31 g/cc. Under the fallow, the density was homogeneous and increased with depth from 1.09 g/cc in the upper 0–20 cm layer till 1.19 g/cc in the 30–70 cm soil layer (Table 3).

Long-term application of the organic system of fertilization promoted the increase in the level of total cleavability up till 54–55 %, and the ratio of the volume of cleaves, occupied by moisture, to the volume of cleaves with air in the 0–20 cm layer of chernozem was from 0.81 to 1, which is 1.32 times higher compared to the intense system of fertilization and related to qualitative changes in the structural condition due to the increase in the content of agronomically valuable aggregates and the most valuable structural units, sized 2–5 mm. The value of total cleavability in the 30–40 cm soil layer increased under the organic sys-

Table 2. The structural composition of regraded chernozem under long-term application of different systems of fertilization

Soil layer, cm	Number of dry aggregates, size, mm; content, %			C_{str}	Estimation
	> 10	10–0.25	< 0.25		
The intense system of fertilization:					
0–20	50.9	45.2	4.00	0.83	Satisfactory
30–40	26.6	69.2	4.20	2.25	Good
The organic system of fertilization:					
0–20	17.1	71.8	11.1	2.53	Good
30–40	13.5	82.5	4.02	4.71	Excellent
Fallow					
0–20	1.00	88.0	11.0	7.43	Excellent
30–40	9.21	83.9	6.90	5.21	Excellent
$HIP_{0.95}$ (0–20 cm)		9.0	5.0	–	–
$HIP_{0.95}$ (30–40 cm)		10.0	–	–	–

Table 3. The long-term impact of fertilization systems on the agrophysical condition of regraded low-humus medium-clay chernozem

Depth, cm	Density of structure, g/cc	Total cleavability, vol. %	Volume of cleaves, vol.%:		The ratio, A to B
			with moisture A	with air B	
The intense system of fertilization:					
0–20	1.25	53.0	20.0	33.0	0.61 to 1
30–40	1.25	53.0	23.0	26.0	0.88 to 1
The organic system of fertilization:					
0–20	1.19	55.0	25.0	31.0	0.81 to 1
30–40	1.20	54.0	24.0	30.0	0.80 to 1
Fallow					
0–20	1.11	58.0	23.0	35.0	0.64 to 1
30–40	1.19	55.0	23.0	32.0	0.72 to 1
$HIP_{0.95}$	0.03	2.0	–	–	–

tem of fertilization towards the maintenance of fallow, and the ratio of the categories of cleaves with moisture and air was in the range of 0.80–0.88 to 1. According to N.A. Kachynsky, the estimation of total cleavability under the intense system of fertilization was satisfactory, while the systematic application of the organic system of fertilization approximated the level of total cleavability to the cultural state.

The improvement of agrophysical properties of regraded chernozem under the organic system of fertilization is related to the increase in the number of warms in the layer of humus horizon of 0–20 cm: their number increases 1.65–1.8 times compared to the intense system of fertilization, which increases the tillage of the processed chernozem layer by 15–25 %, the increase in total cleavability and the increase in microaggregation similar to the maintenance of fallow.

In recent agricultural practice, the investigation of solidness is conducted to characterize the rheological state and quality of some kinds of soil tillage as well as diagnostics of agrophysical degradation of soils.

The determination of the solidness of the tilled layer (0–30 cm) of regraded chernozem was conducted along with the density of its structure (Table 4). The solidness under the intense system of fertilization was considerably higher compared to the organic system of fertilization which correlates (R=0.67–0.75±0.02) with the density of structure, lumpiness, and connectivity of chernozem.

The increase in microaggregation, the restoration of structural state, qualitative change in cleaved environment under the organic system of fertilization are related to the improvement of humus and physical-chemical state of regraded chernozem (Table 5).

For instance, the exchange acidity ($pH_{(l)}$) in the soil layer of 0–20 cm increased by 112 %, or by 0.63 units of pH, which is remarkable for under-arable horizons as well: Δ $pH_{(l)}$=+0.95 regarding the intense system of fertilization. The value of the hydrolytic acidity under the organic system of fertilization decreased 1.38–1.65 times which resulted in the increase in the sum of absorbed alkali by 1.0–2.8 mg-eq per 100 g of soil.

The application of the organic system of fertilization for 7 years promotes the improvement of the humus condition of regraded chernozem. For instance, the content of humus in the 0–20 cm layer of chernozem increased by 0.31 %, in the 30–40 cm soil layer – by 0.07 % which affected the reserves of humus that in-

Table 4. The solidness of regraded chernozem depending on fertilization systems under long-term application

The system of fertilization	Depth, cm; kg/sq.cm.					
	5	10	15	20	25	30
Intense	23.5	25.7	23.4	31.2	17.3	13.0
Organic	9.8	11.5	13.0	11.9	11.5	10.0
±	–13.7	–14.2	–10.4	–19.3	–5.8	–3.0
$HIP_{0.95}$	10.0	8.0	7.0	10.0	5.0	3.0

Table 5. The humus and physical-chemical state of regraded chernozem depending on fertilization systems under long-term application

Performance, cm	Reserves of humus, (tons/ha)	$pH_{(кcl)}$	Hydrolytic acidity (Hr)	The total of absorbed alkali
			Mg-eq/100 g	
*The intense system of fertilization:				
0–20	63.0	5.48	2.56	27.4
30–40	28.0	5.80	1.87	28.0
0–40	116	5.66	2.15	27.4
The organic system of fertilization:				
0–20	75.0	6.11	1.85	30.2
30–40	26.0	6.75	1.13	29.0
0–40	131	6.39	1.55	29.4
$HIP_{0.95}$	13.0	0.05	0.58	1.5

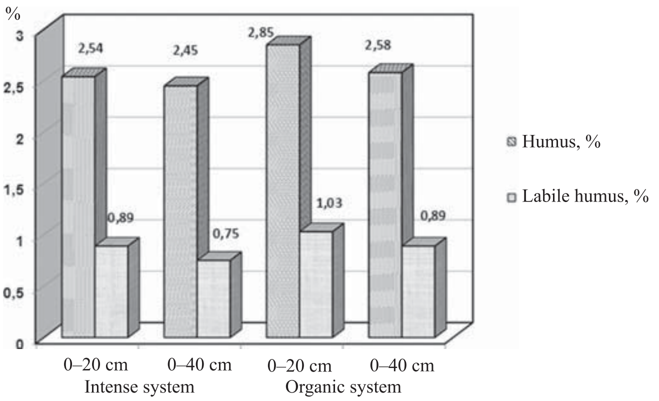

Fig. 4. The effect of different systems of fertilization of the content of humus and its qualitative composition

creased by 12 and 2 t/ha regarding the intense system of fertilization. Generally, the content of humus in the humus horizon (0–40 cm) increased by 0.15 % which impacted the humus reserves that increased by 15 t/ha. Under the organic system of fertilization, the content of labile humus increased both in the 0–20 cm chernozem layer and in the humus horizon in general: the increase regarding the intense system of fertilization was 1.19–1.21 times (Fig. 4).

The improvement of agrophysical, physical-chemical properties and humus condition of regraded chernozem and the manifestation of agroecosystem performance at the level of strong immediate dependence correlates with the parameters of nitrogen balance, C_{org} and the intensity of nitrogen-carbon circulation [8–12]. It was established that regardless of the system of fertilization, the nitrogen balance was positive, but the surplus of nitrogen balance under the organic system of fertilization was 1.78 times less and the balance intensity – by 9–10 % smaller compared to the intense system of fertilization.

A strong immediate correlation (R=+0.85±0.03) was found between the performance of agroecosystem and the capacity of nitrogen balance: under the organic system of fertilization the capacity of balance was 1.26 smaller compared to the intense system of fertilization (Table 6). The consideration of the intensity of the nitrogen cycle is related to the increase in the terrestrial carbon content which is caused by the increased CO_2 content in the atmosphere and the intensification of mineralization processes in soil, which results in terrestrial accumulation of available mineral nitrogen, stimulating the performance of agroecosystems and intensifying the productivity of photosynthesis [13, 14]. In case of a sufficient level of the mentioned processes the need for atmospheric carbon in plant aggregations

Table 6. The indices of performance and balance parameters for nitrogen, organic carbon and CO_2 under the application of different systems of fertilization in 2016–2010

*Performance f.u. f.p.u. tons/ha	Parameters of circulation								
	of nitrogen			$C_{org.}$			CO_2		
	Balance of nitrogen, kg/ha	Intensity of balance, %	Capacity of balance, kg	Balance of C_{org} tons/ha	Intensity of balance, %	Capacity of balance, tons	Balance of CO_2, tons/ha	Intensity of balance, %	Capacity of balance, tons
The intense system of fertilization:									
6.75 / 6.45	+80.0	125	745	+0.49	125	4.15	–6.0	88.0	95.0
The organic system of fertilization:									
5.51 / 5.35	+45.0	115	590	+0.53	135	3.85	+1.35	105	80.0
$HIP_{0.95}$									
1.05 / 0.95	+25.0	7.0	90.0	+0.05	8.0	0.25	–	10.0	12.0w

*f.u. – feed units; f.p.u. – feed protein units.

starts exceeding the emission of carbon in soil, while terrestrial eco- and agroecosystems get transformed into systems – accumulators of atmospheric organic matter, *i.e.* the carbon-climate interaction becomes an inverse correlation model [15, 16]. As a rule, climate warming leads to the decrease in CO_2 depositing in agroecosystems which is related to the increase in the intensity of both productive and destructive processes: the rate of organic matter decomposition in soil is enhanced, soil breathing is intensified which results in the increase in the sensitivity of performance of different plant aggregations to soil humidity and air temperature. In case of excessive manifestation of the abovementioned processes, the intensity of soil breathing starts exceeding the rate of atmospheric CO_2 accumulation by plants, and agroecosystems transform into the sources of emission of carbon dioxide and nitrous oxide into the atmosphere [17, 18].

The application of the organic system of fertilization affected the circulation parameters for C_{org} which tended to increase, the surplus was 109 % higher which resulted in the increase in the balance intensity by 10–15 % but at the background of the 1.07–1.1-fold decrease in the capacity of balance compared to the intense system of fertilization. The estimation of the circulation parameter for CO_2 in the agroecosystem demonstrated that CO_2 balance under the organic system of fertilization was positive but the balance capacity for CO_2 was 10 tons smaller compared to the intense system of fertilization which testified to the stock nature of C_{org} and CO_2 in agroecosystems under the organic system of fertilization. Under the organic system of fertilization, the ratio of C_{org} to N in the agroecosystem was from 27–30 to 1, whereas under the intense system it was from 22–23 to 1. In the former case, there is prevalence of the processes of reserving C_{org} in soil, and those of humus accumulation, and in the latter – the increase in humus mineralization. Taking into consideration the state of parameters for nitrogen balance, C_{org} and CO_2 there is an explanation of the decrease in the performance for the five-field grain-growing and weeding crop rotation with the yield of f.u. and f.p.u.: the decrease in the yield was 1.24 and 1.1 t/ha respectively.

The dynamics of the yield for winter wheat and spring barley (Fig. 5) demonstrated that the performance of grain changed towards the increase regardless of the fertilization system. The average performance of winter wheat under the intense system of fertilization was 5.11 t/ha which was 0.36 t/ha higher than the yield under the organic system of fertilization.

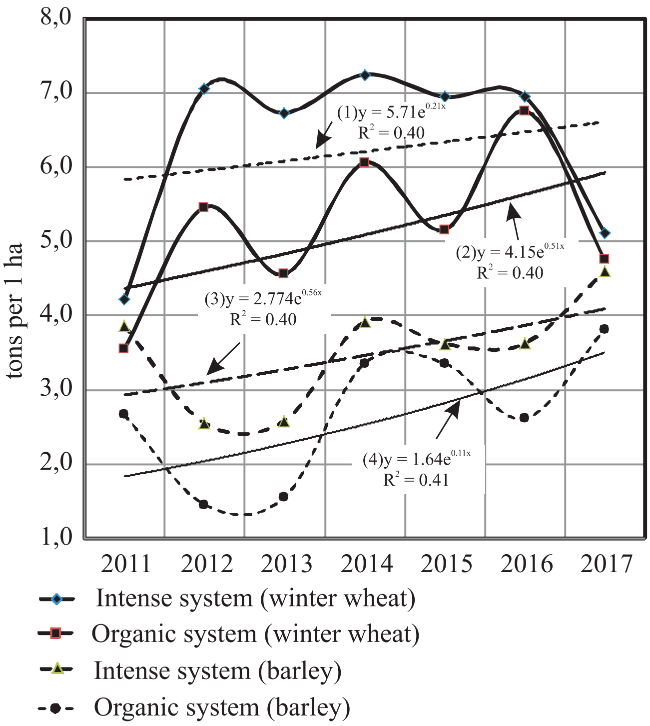

Fig. 5. The dynamics of the yield of winter wheat and spring barley depending on the fertilization system in 2011–2017

The average performance of spring barley under the intense system of fertilization was at the level of 4.59 t/ha which was 0.78 t/ha higher than the yield under the organic system of fertilization. The trends of changes in the performance of winter wheat and spring barley under the organic system of fertilization are sharper compared to the intense system of fertilization: regression coefficients for the variable x (t/ha) in the former case are 2.43 and 1.96 times higher compared to the latter case of fertilization which testifies to ф more intense increase in the performance of cereals under the organic system of fertilization.

The dynamics of protein content, regardless of the fertilization system, was increasing and the average value of the content under the organic system was 12.83 against 13.63 % under the intense system of fertilization. There were similar changes in the content of gluten with the average content of 25.69 against 27.07 % according to the systems of fertilization. The trends of changes in the content of protein and gluten under the organic system of fertilization were sharper compared to the intense system of fertilization: the regression coefficients were 1.53–1.56 times higher for the variable x (%). The application of the organic system of fertilization promotes the increase in the grain yield of winter wheat by 0.051 t/ha with simultaneous increase in the content of protein and gluten by 0.033–

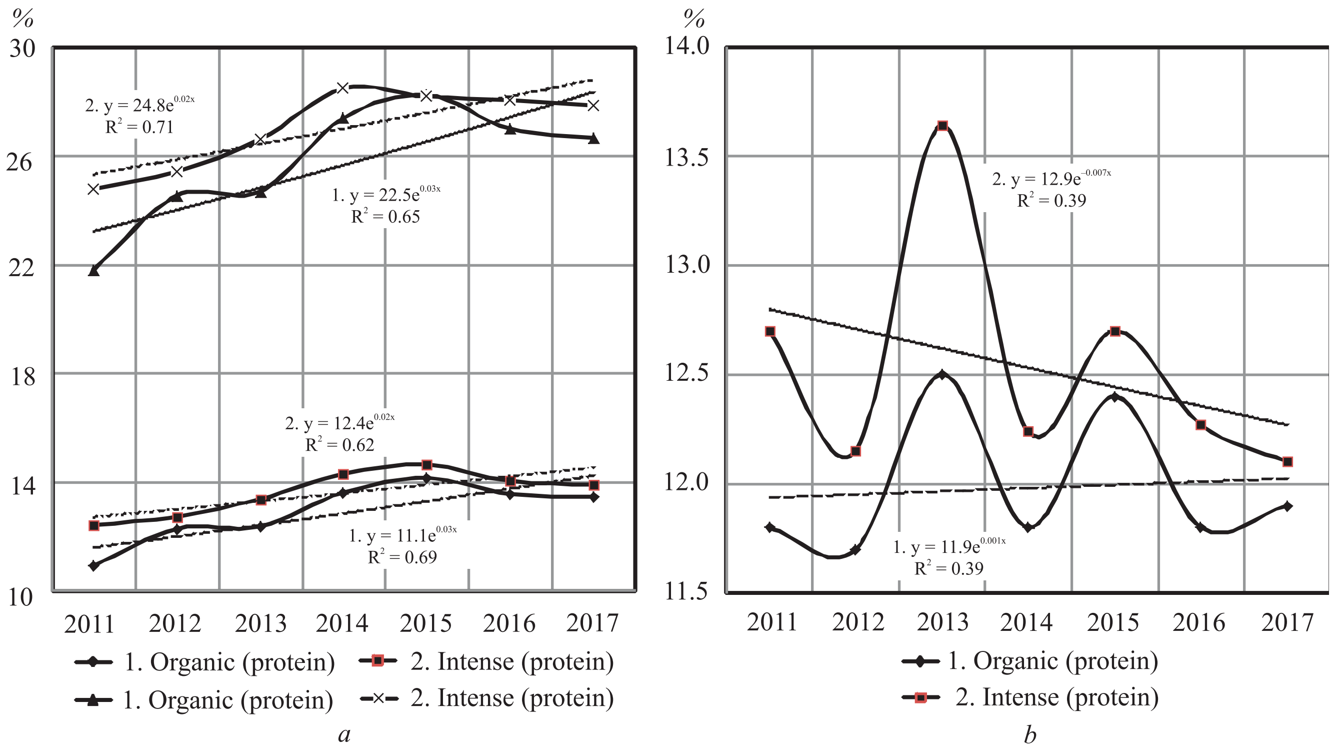

Fig. 6. The dynamics of the grain quality of winter wheat (A) and spring barley (B) depending on the fertilization system in 2011–2017

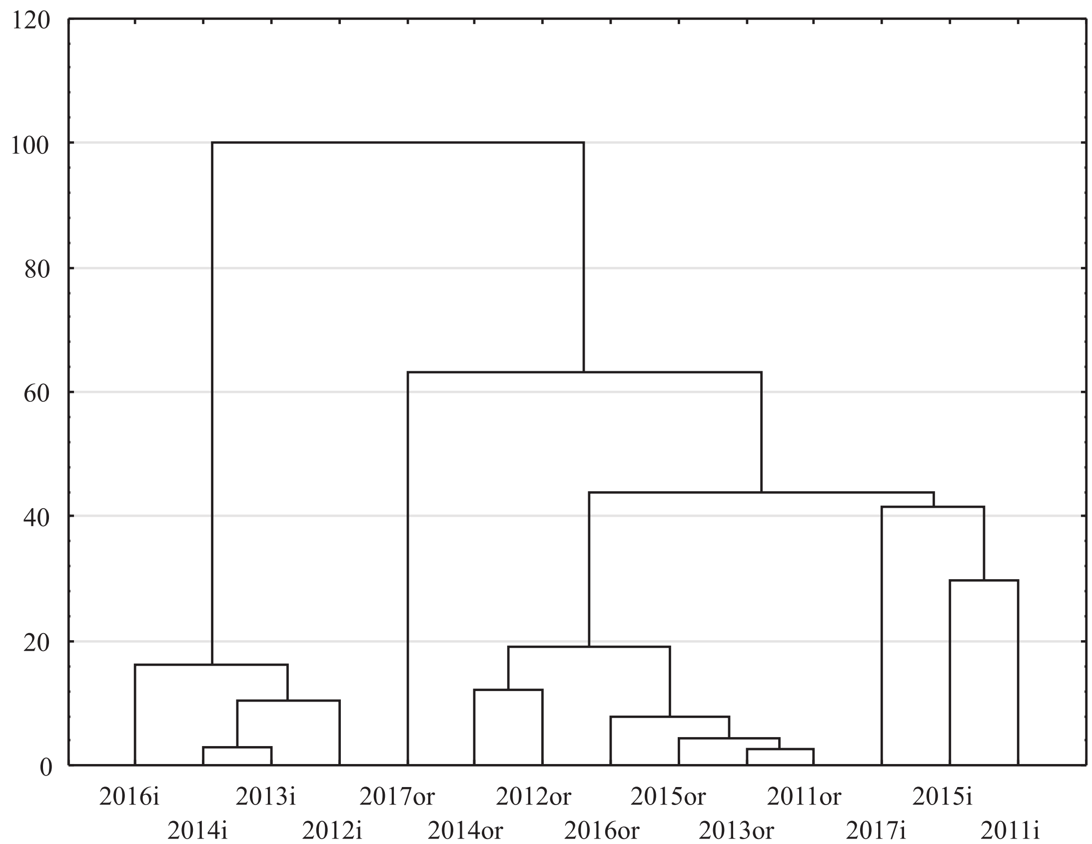

Fig. 7. The clusterization of fertilization systems under short grain growing and weeding crop rotation in the years of studies: index (i) – intense system; (or) – organic system of fertilization

0.034 % per year. Under the organic system of fertilization, the average content of protein in a grain of barley was 11.99 %, and under the intense system – 12.54 %. The dynamics of a trend under the organic system of fertilization was increasing, whereas there was a decreasing trend under the intense fertilization system. In the first case the increase in protein content was 0.0012 % and in the second one – 0.007 % per year (Fig. 6).

The conducted clusterization of fertilization systems by the parameters of the structure of total phytomass, the components of nitrogen, carbon and CO_2 circulation (a total of 42 parameters) demonstrated that the organic system of fertilization formed a cluster by the years of observations at the level of 20 %. Under the intense system of fertilization there is the following clusterization by the years of performance manifestation: 2012–2014, 2016 at the level of 18 %, and 2011, 2015, 2017 – at the level of 40 % similarity which testifies to a reliable difference between the systems of fertilization and the completion of the biologization period of soil conditions or a transient period after the end of application of the intense system of fertilization (Fig. 7).

CONCLUSIONS

The complex agrophysical, physical-chemical substantiation and balance estimations proved the increasing efficiency of the organic fertilization system in the agroecosystem of five-field grain-growing and weeding crop rotation with the saturation using cereals and legumes up to 40 % and the use of by-products for fertility restoration and improvement of the agrogenesis of regraded chernozem in the central part of the Forest-Steppe of Ukraine as a basis for organic production.

The systematic application of the organic system of fertilization in a short grain-growing and weeding crop rotation with the use of by-products as organic fertilizers promotes the increase in the points of exchange neutrality and the decrease in the unsaturation of regraded chernozem with the alkali of the tilled layer, while the increase in microaggregation and structure-building is conditioned by the approximation of potential acidity to the isoelectric state of soil colloids which is a feature of the process of biologization and simulation of natural soil formation in agroecosystems of the central part of the Forest-Steppe of Ukraine.

Under the organic fertilization system the decrease in the agroecosystem performance is related to the decrease in the capacity of nitrogen and organic carbon balance which testifies to the decrease in the intensity of its circulation in agroecosystem: the processes of enhancing the humification of by-products and the formation of prohumus substances prevail, accompanied with the intensification of atmospheric CO_2 involvement in the formation of the total phytomass of the harvest, which transforms the agroecosystem into a stock system, which serves as a basic system for organic production of plant cultivation.

The elaborated system of organic fertilization of crops in a five-field grain-growing and weeding crop rotation allows avoiding the use of organic fertilizers and perennial grasses and using by-products of plant cultivation instead to saturate the crop rotation with legumes up to 30–40 %, it allows ensuring the production of organically pure products with simultaneous restoration of fertility and restoration of the natural model of the chernozem agrogenesis of the central part of the Forest-Steppe of Ukraine.

The systematic application of the organic system of fertilization for 7 years allows adjusting the condition of regraded chernozem to the state of fertility restoration, the completion of the biologization period of soil conditions, which is confirmed by the increasing trends for the yield and quality of the production, the rapidness of increase which prevails over the tempos of the increase in the yield trends and grain quality under the intense system of fertilization.

Агрогенез чорнозему реградованого і продуктивність зернових культур за органічної системи удобрення

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Ціль. Провести комплексне агрофізичне, фізико-хімічне, за балансом азоту, органічного вуглецю обгрунтування ефективності органічної системи удобрення в агроценозі 5-пільної зерно-просапної сівозміни з насиченням зерно-бобовими культурами до 40% і використання побічної продукції на відтворення родючості та посилення агрогенезу чорнозему реградованого центральної частини Лісостепу України. **Методи.** Лабораторно-аналітичний, експериментально-польовий, розрахунковий, статистичний. **Результати.** Систематичне застосування органічної системи удобрення в коротко-ротаційній зерно-просапній сівозміні з використанням побічної продукції у якості органічних добрив сприяє підвищенню точок обмінної нейтральності і зниженню ненасиченості основами оброблюваного шару чорнозему реградованого, а посилення мікроагрегування та оструктурення зумовлено наближенням потенційної кислотності до ізоелектричного стану ґрунтових колоїдів, що є ознакою процесу біологізації та моделюванням природного ґрунтоутворення в агроценозах центральної частини Лісостепу України. За органічної системи удобрення зниження продуктивності агроценозу пов'язано зі зменшенням ємності балансу азоту, що свідчить про зниження інтенсивності його обігу в агроценозі: переважають процеси посилення гуміфікації побічної продукції та утворення прогумусових речовин, які супроводжуються інтенсифікацією залучення CO_2 атмосфери до формування загальної фітомаси урожаю, а агроценоз перетворюється на стокову систему, яку можна охарактеризувати як базова система для органічного виробництва продукції рослинництва. **Висновки.** Розроблена система органічної удобрення культур в 5-пільній зерно-просапній сівозміні дає можливість, не застосовуючи органічних добрив і багаторічних трав, а використовуючи побічну продукцію рослинництва з насичення сівозміни бобовими культурами до 30–40 %, застосовуючи азотфіксуючі та фосфатмобілізуючі препарати, забезпечити виробництво органічно чистої продукції з одночасним відтворенням родючості і відтворенням природної моделі агрогенезу чорнозему центральної частини Лісостепу України.

Ключові слова: мікроагрегати, щільність будови, гумус, баланс, органічний вуглець, сівозміна, побічна продукція, кормові і зернопротеїнові одиниці.

Агрогенез чернозема реградированного и продуктивность зерновых культур при органической системе удобрения

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Цель. Провести комплексное агрофизическое, физико-химическое, по балансу азота, органического углерода обоснование эффективности органической системы удобрения в агроценозах 5-польного зернопропашного севооборота с насыщением зернобобовыми культурами до 40 % и использовании побочной продукции на воспроизводство плодородия и усиления агрогенеза чернозема реградированного центральной части Лесостепи Украины. **Методы.** Лабораторно-аналитический, экспериментально-полевой, расчетный, статистический. **Результаты.** Систематическое применение органической системы удобрения в короткоротационном зерно-пропашном севообороте с использованием побочной продукции в качестве органических удобрений способствует повышению точек обменной нейтральности и снижению ненасыщенности основаниями обрабатываемого слоя чернозема реградированного, а усиление микроагрегирования и оструктуренности обусловлено приближением потенциальной кислотности к изоэлектрической точке состояния почвенных коллоидов, что является признаком процесса биологизации и моделированием природного почвообразования в агроценозах центральной Лесостепи Украины. При оргнической системе удобрения снижение производительности агроценоза связано с уменьшением емкости баланса азота, что свидетельствует о снижении интенсивности его оборота в агроценозе: преобладают процессы усиления гумификации побочной продукции и образования прогумусовых веществ, сопровождающихся интенсификацией привлечения CO_2 атмосферы к формированию общей фитомассы урожая, а агроценоз превращается в стоковую систему, которую можно охарактеризовать как базовая система для органического производства продукции растениеводства. **Выводы.** Разработанная система органического удобрения культур в 5-польном зернопропашном севообороте дает возможность, не применяя органических удобрений и многолетних трав, а используя побочную продукцию растениеводства при насыщении севооборота бобовыми культурами до 30–40 % и применяя азотфиксирующие и фосфатмобилизирующих препараты, обеспечить производство органически чистой продукции с одновременным воспроизводством плодородия и естественной модели агрогенеза чернозема центральной части Лесостепи Украины.

Ключевые слова: микроагрегаты, плотность сложения, гумус, баланс, органический углерод, севооборот, побочная продукция, кормовые и зернопротеиновые единицы.

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