Conference Paper

Influence of Long-Term Application of Fertilizer Systems on Fertility of Ordinary Carbonate Chernozem in the Conditions of the Central Ciscaucasia

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Abstract

The paper studies the influence of systematic application recommended and estimated mineral ($N_{69}P_{63}K_{45}$ and $N_{141}P_{68}K_{60}$) and organomineral (manure 8 t/ha + $N_{44}P_{42}K_{24}$and manure 15 t/ha + $N_{87}P_{36}K_{7}$) fertilizer systems within grain-grass-hoe crop rotation on density, porosity, structural condition of soil, water stability of structural units, water permeability, change of humus content and basic nutrition elements in rainfed conditions and at irrigation in comparison with their initial content and with indicators in control option -- without fertilizers and irrigation throughout long-term field experiment on ordinary carbonate chernozem in a steppe zone of the Central Ciscaucasia. It is defined that over 68 years of experiments the content of total nitrogen, phosphorus, potassium and reaction of soil solution did not change. The maximum losses of humus and available forms of nutritious elements occurred in options without fertilizers in rainfed and irrigated conditions, bulk density of soil increased, porosity and water permeability decreased. The use of fertilizers improved agrophysical and water properties of soil: its density decreased, porosity, structure index, water stability, water permeability and hygroscopicity increased. The introduction of estimated organomineral fertilizer system to the scheme of experiment since 1986 restored the humus content in soil to the reference value and ensured its positive balance (+2.6 t/ha).

Keywords: ordinary chernozem, fertilizer systems, soil density, porosity, water permeability, water stability, humus, labile phosphorus, potassium

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1. Introduction

Land resources of Russia occupy about 10% of the total area of the world agricultural lands. The level of their fertility mainly depends on anthropogenic factors and is characterized by the violation of circulation of elements and energy in agroecosystems, loss of humus, exchange bases, decrease of soil buffering, soil acidulation. Anthropogenic load on soil in the 1980--1990s of the 20th century was considerably increased due to intensified agriculture to increase the efficiency of agroecosystems. Intensification of technologies always implies high level of fertilizer element removal, which return at the

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present stage of management and economic relations is difficult to renew [1--4]. The problem of soil fertility on irrigated lands is especially urgent. In Central Ciscaucasia 30 % of agricultural lands are presented by ordinary chernozems, about 50 % of them are irrigated. Excessive removal of fertilizer elements compared to their receipt to the soil leads to noncompensated spending of soil fertility reserves and violation of the law of returning, as well as to the reduction of efficiency of arable lands caused by deterioration of soil fertility. Soil conservation defines the relevance and the need for methods of its reproduction, which shall mainly be aimed at the replenishment of organic matter and positive balance of humus and basic fertilizers, which is not sufficiently studied within specific soil climatic conditions.

2. Materials and Methods

The purpose of the study is to analyze the influence of long-term application of different mineral and organomineral fertilizer systems on bogara and at long irrigation on crop yield rotation, efficiency of arable lands, dynamics of water and nutritious modes of soil and change of key indicators of fertility of ordinary carbonate chernozem in a steppe zone of the Central Ciscaucasia (Opytnoye rural settlement, Kabardino-Balkar Republic). The study was conducted within long stationary field experiment launched in 1948 (experiment No. 037 of the Geographical network of experiments with fertilizers). In 10-pole grain-grass-hoe crop rotation in all fields in space with crop rotation in time, in bogara and irrigated conditions the following options of fertilizer systems were studied: 1 -- without fertilizers and irrigations (control); 2 -- mineral ($N_{69}P_{63}K_{45}$) without irrigation; 3 -- organomineral (manure 8 t/ha + $N_{44}P_{42}K_{24}$) without irrigation; 4 -- without fertilizers at irrigation; 5 -- mineral ($N_{69}P_{63}K_{45}$) at irrigation; 6 -- organomineral (manure 8 t/ha + $N_{44}P_{42}K_{24}$) at irrigation; 7 -- estimated mineral ($N_{141}P_{68}K_{60}$) at irrigation; 8 -- estimated organomineral (manure 15 t/ha + $N_{87}P_{36}K_{7}$) at irrigation. In options 2, 3, 5 and 6 the recommended fertilizer systems experimentally installed earlier in short-term field experiments as optimum for different cultures of crop rotation were studied. The estimated fertilizer systems were defined by a balance method taking into account personal long-term studies to preserve and reproduce soil fertility and planned efficiency of crop rotation at 5.0--5.3 thousand grain units/ha and were introduced into the experimental design since 1986 via splitting of plots [4]. Soil humidity at irrigation was maintained by watering at the level of 75--80 %. The total number of options in the experiment is 100, crop rotations -- 4. Double frequency. The total area of a plot after splitting makes 165.6 m^2, estimated -- 20.0; 48.0 and 81.6 m^2depending on culture.

At the beginning of the experiment the soil of the pilot site was characterized by the following indicators: reaction of soil solution was neutral or close to neutral (pH 6.9--7.2), humus content in top horizons made 3.50--3.65 %, total nitrogen in soil -- 0.20--0.28 %, phosphorus -- 0.13--0.19 %, potassium -- 2.0--2.2 %. Carbon-nitrogen ratio (C:N) narrow -- 7.5--9.0. Depth of horizons A+B -- 75 cm. The absorbing complex is mainly rich in cations of calcium and magnesium, total absorbed bases -- 25--30 mg-eq/100 of soil. High nitrification capacity, more than 3 mg/100 g, content of labile phosphorus -- 2.0--2.5, available potassium -- 30--40 mg/100 g of soil. Carbonates were present in the entire soil profile. Content of physical clay -- 45--60 %. Concerning the particle-size distribution (across Kachinsky) the soil is heavy loamy, silty and dusty, total porosity is more than 50 %. Agrophysical properties of soil are good and satisfactory. The smallest moisture capacity of a meter layer makes 24.5--25.4 % of the dry soil mass [5]. Heavy and loamy ordinary carbonate chernozem with mycelial-calcareous air-borne loessial loam as the mother rock was used as an object of study. Soil samples were collected from arable horizons and soil layers of 20 cm according to VNIIA methodical instructions [6, 7].

Agrochemical analyses of soil were made by the following methods: pH -- potentiometric method, soil humus -- Tyurin's method, nitrate nitrogen -- Grandval-Lajoux method, labile phosphates and potassium -- from one extract by Machigin's method [8], soil structure and related properties -- by international methodological guidelines [9].

3. Results

One of the main tasks of the experiment was to define the influence of systematic long-term application of fertilizers and regular irrigation on agrochemical and agrophysical properties of ordinary carbonate chernozem that was described by us earlier [10, 11]. Irrigation and fertilization were the major factors affecting agrophysical and water properties of soil. Soil consistency is characterized by density (bulk weight), particle density (specific weight) and porosity (pore space). Over a long period of experiments, irrigation had the most significant effect on bulk density and porosity of soil. The comparison of soil of control option 1 (without fertilizers and without irrigation) with option 4 (without fertilizers at irrigation) showed density increase in all soil layers by 0.12--0.16 g/cm^3. Porosity at irrigation decreased and made less than 50 % in all soil layers. The density of irrigated soil also increased with the introduction of mineral fertilizers in soil layers of 0--20 and 21--40 cm, the porosity of these layers decreased respectively.

The introduction of mineral and organomineral fertilizers in nonirrigated crop rotation reduced the soil density in comparison with source data of 1948 and with the control option without fertilizers. The application of mineral fertilizers (options 5 and 7) in irrigated crop rotation in comparison with option 4 (without fertilizers at irrigation) reduced the density of all soil layers, but its indicators were above the reference density. The application of organomineral of fertilizer systems -- recommended and estimated -- maintained soil in friable state in comparison with the source data; in comparison with option 4 -- at irrigation without fertilizers -- it reduced the density of 0-40 cm layer by 0.16 g/cm^3 and increased porosity by 4.6 % (Tab. 1). The particle density under the influence of fertilizers in irrigated and nonirrigated crop rotation did not change during the experiment.

One of the key properties of soil is its hygroscopicity -- ability of soil to absorb vaporous water from the atmosphere. The hygroscopic moisture content enveloping the surface of particles in the form of a film and withheld by molecular forces around solid soil particles changes depending on particle-size distribution, humus content, moistening and other reasons and affects the wilting moisture of plants. The highest hygroscopic moisture of ordinary chernozem in nonirrigated conditions was noted with the application of recommended organomineral fertilizer system, i.e. with sufficient amount of humus in soil. In irrigated conditions the highest hygroscopic moisture is noted in the option with the application of estimated organomineral fertilizer system, i.e. with a large amount of humus and optimum moisture of soil.

The soil structure was estimated through the structure index (K_{st}). The highest value is noted in nonirrigated crop rotation in a layer of 0-20 cm with the application of organomineral fertilizer system. At irrigation the soil structure became worse, changes in the option without fertilizers were particularly noticeable (option 4) and with the application of mineral fertilizer systems. Organomineral fertilizers (recommended and estimated) maintained the soil structure thus increasing the content of agronomically valuable fractions by 21.5--26.6 % in comparison with option 4 (without fertilizers at irrigation).

Agronomically valuable water-stable structure of soil is noted in all fertilizer systems in irrigated and nonirrigated crop rotations; the sum of water-stable aggregates equaled 73.1--84.8 % (Tab. 1). The greatest increase in the sum of water-stable aggregates was noticed with the application of organomineral fertilizer systems: recommended (manure 8 t/ha + $N_{44}P_{42}K_{24}$) and estimated (manure 15 t/ha + $N_{87}P_{36}K_{7}$).

Table 1: Influence of irrigation and fertilizer systems on the dynamics of key indicators of agrophysical and water properties of soil (above the line -- for the layer of 0--20 cm, below the line -- 21--40 cm).

Year	Option							
	without irrigation				irrigation			
	1	2	3	4	5	6	7	8
				Soil density, g/cm^3				
1948	1.20/1.34	1.20/1.34		1.20/1.34	1.20/1.34			
1968		1.21/1.32			1.30/1.32			
1978		1.19/1.23			1.26/1.35			
1993--1996	1.22/1.25	1.20/1.25	1.17/1.22	1.34/1.41	1.27/1.36	1.22/1.28	1.26/1.34	1.19/1.24
1	2	3	4	5	6	7	8	9
2005--2007	1.22/1.27	1.20/1.25	1.17/1.21	1.34/1.41	1.27/1.36	1.22/1.28	1.26/1.27	1.19/1.24
2016--2017	1.22/1.30	1.21/1.26	1.17/1.21	1.34/1.41	1.26/1.36	1.22/1.28	1.25/1.27	1.20/1.24
				Particle density, g/cm^3				
1948	2.56/2.59	2.56/2.59		2.55/2.60	2.55/2.60			
1968		2.53/2.60			2.60/2.60			
1978		2.53/2.58			2.55/2.60			
1993--1996	2.55/2.59	2.53/2.58	2.54/2.57	2.55/2.65	2.54/2.60	2.53/2.62	2.52/2.58	2.53/2.57
2005--2007	2.54/2.59	2.53/2.58	2.54/2.57	2.55/2.65	2.54/2.60	2.53/2.61	2.52/2.58	2.53/2.57

Year	Option							
	without irrigation				irrigation			
2016--2017	2.54 / 2.59	2.53 / 2.59	2.54 / 2.57	2.55 / 2.64	2.54 / 2.60	2.53 / 2.61	2.52 / 2.59	2.53 / 2.58
	Porosity, %							
1948	53.1 / 48.3	53.1 / 48.3		52.9 / 48.5	52.9 / 48.5			
1968		52.2 / 49.2			50.0 4 / 9.2			
1978		53.0 / 52.3			50.6 / 48.1			
1993--1996	52.1 / 51.7	52.6 / 51.6	53.9 / 52.9	47.4 / 46.8	50.0 / 47.7	51.8 / 51.8	50.0 / 48.1	52.9 / 51.7
2005--2007	51.9 / 50.9	52.6 / 51.6	53.9 / 52.4	47.5 / 46.8	50.0 / 47.7	51.7 / 50.9	50.0 / 50.7	52.9 / 51.7
2016--2017	51.9 / 49.8	52.1 / 51.3	53.9 / 52.9	474 / 46.6	50.4 / 47.7	51.7 / 50.9	50.4 / 50.9	52.5 / 51.9
	Structure index, K_{st}, %							
1993--1996	2.14 / 1.78	2.26 / 1.86	2.30 / 1.88	1.64 / 1.53	1.68 / 1.72	2.04 / 1.80	181 / 1.72	2.14 / 1.87
2005--2007	2.17 / 1.87	2.18 / 1.86	2.27 / 1.86	1.69 / 1.60	1.70 / 1.73	1.94 / 1.76	1.83 / 1.78	2.121.83
2016--2017	2.16 / 1.86	2.23 / 1.88	2.31 / 1.90	1.68 / 1.59	1.74 / 1.72	2.05 / 1.84	1.88 / 1.79	2.17 / 1.89
	Water stability, %							
1993--1996	75.1 / 71.9	76.8 / 78.0	82.0 / 84.8	73.4 / 72.5	74.5 / 77.5	77.6 / 78.3	75.2 / 75.0	80.4 / 84.8
2005--2007	74.9 / 72.3	76.7 / 78.2	83.9 / 83.7	73.1 / 74.0	77.9 / 76.1	79.2 / 79.4	80.7 / 80.4	81.4 / 83.3

Year	Option							
	without irrigation				irrigation			
2016--2017	75.0	76.9	83.8	73.0	78.1	79.4	81.1	81.9
	72.1	78.2	84.0	73.8	77.6	79.5	79.9	84.2
Water permeability, mm/min								
1948	0.88--1.50							
1993--1996	1.25	1.36	1.68	0.51	1.26	1.66	1.31	1.73
2005--2007	1.25	1.36	1.68	0.51	1.26	1.66	1.33	1.75
Hygroscopic moisture, %								
1993--1996	4.44	4.95	5.11	4.21	4.30	4.51	4.32	4.61
	4.00	4.39	4.64	3.78	3.95	4.21	4.10	4.31

Water permeability of soil defined prior to the experiment was within the range of 1.5--0.88 mm/min [5]. It was found that at long-term use of the recommended mineral fertilizer system the water permeability of nonirrigated soil increased by 9 % in comparison with the control option. The use of recommended organomineral fertilizer system increased water permeability by 34 %. Regular irrigation worsened the water permeability of non-fertilized soil to 0.51 mm/min, which is 59 % less than the control option. The application of recommended and estimated mineral fertilizer systems in irrigated conditions maintained water permeability at the level of the control option. Long-term use pf organomineral fertilizer systems increased water permeability of ordinary chernozem by 33--38 % in comparison with the control option and by 10--12 % in comparison with initial water permeability of soil before the experiment [5].

The content of humus in soil is one of the main indicators of soil fertility [12--19]. Prior to the experiment in a 0--20 cm layer of soil it made on average 3.55 % changing from 3.46 to 3.58 % [5]. The experiment before 1965 did not include observations on the change of humus, in 1970 the levels of its content typical for each fertilizer system were defined. Since 1970 the humus content in the main options of the experiment changed slightly, which indicated an equilibrium condition of humification and mineralization of organic matter under the influence of fertilizer and irrigation systems [4, 10, 11].

In the soil of option 1 (without fertilizers) in nonirrigated crop rotation the most significant losses of organic matter happened for 2 rotations: 20.1--21.0 t/ha in a 0--20 cm layer. The humus content in this option was stabilized at the level of 2.71--2.82 % by the end of the III rotation (1979), which is also noted at present. The average efficiency of crop rotation in the control option over 6 analyzed rotations (from 1960 to 2016) made 1.72 thousand grain units/ha increasing from dry to wet years by 2.3--2.5 times -- from 0.85 to 2.03 thousand grain units/ha. In option 2 with the application of the recommended mineral fertilizer system the content of humus at the beginning of the III rotation made 3.02--3.10 % and was on average by 0.45 % less than initial value. By 1970 the losses of humus in a 0--20 cm layer made 10.0--10.7 t/ha thus stabilizing at this level during 4 subsequent rotations. The humus content was increasing in VII rotation in option 2, which is explained by large volumes of organic matter in soil due to crop yield growth in 2010-2015. At systematic introduction of the recommended mineral fertilizers for the cultures of bogar crop rotation -- $N_{69}P_{63}K_{45}$on average per 1 year of rotation -- the increase of its efficiency in comparison with the control option made 0.96 thousand grain units/ha over 6 rotations changing depending on the amount of rainfall by 60--66%.

With the application of the recommended organomineral fertilizer system the humus content in nonirrigated ordinary chernozem almost did not change over 66 years of the experiment. All changes were rather seasonal illustrating a positive balance of humus in all years (Tab. 2). Systematic application of organomineral fertilizer system (option 3) -- manure 8 t/ha + $N_{44}P_{42}K_{24}$ -- ensured an average increase of crop rotation efficiency over 6 rotations by 1.16 thousand grain units/ha (72 % compared to the control option). The productivity of crop rotation and efficiency of fertilizer systems without irrigation increased from dry to wet years by 2.4--2.5 times. The recommended organomineral fertilizer system ensured stable harvest, which level increased with the improvement of water availability of the year, and created conditions for preservation and reproduction of ordinary chernozem fertility in nonirrigated (bogara) agriculture.

The lowest level of humus in soil was defined in the option without fertilizers at irrigation. In 1970 the humus content in soil samples of option 4 made 0.25% less than in the control (option 1) and 0.79 % less the reference value. The soil of option 4 was characterized by the biggest losses of humus -- 21.3--21.7 t/ha, the content of all fertilizer elements decreased in comparison with initial indicators. It shall be noted that their main losses happened in the first two rotations [4, 10, 11]. With the application of the recommended mineral fertilizer system (option 5) the humus content in irrigated soil decreased by the end of the III rotation up to 2.80--2.90 %. The application of the recommended organomineral system also did not maintain the level of humus content at irrigation. At the end of the III rotation it decreased up to 3.20 % and stayed at this level prior to the VII rotation when small increase in its content -- up to 3.28--3.30 % -- was noted.

Over 29 years of application of the estimated mineral fertilizer system at irrigation (option 7) the humus losses decreased, the humus content increased from 2.78 to 3.18--3.20 % that occurred due to the increase of crop and root remains connected with increased crop yield. The application of estimated (option 8) organomineral fertilizer system in the conditions of irrigation from 1986 to 1996 restored the humus content to initial level and since 1996 till present (2015) it ensured sufficient balance of humus in soil.

Extensive use of arable lands without fertilizers (options 1 and 4) reduced the content of humus and labile forms of all fertilizer elements in comparison with their initial indicators prior to the experiment. The main changes happened in the first 2 rotations. Further the content of available fertilizer elements in options without fertilizers changed slightly. No changes in total nitrogen, phosphorus and potassium in the studied soil were noted.

The content of labile phosphorus in soil with the use of all mineral and organomineral fertilizer systems was increased from rotation to rotation. Already in the III rotation in the soil of nonirrigated crop rotation with the application of fertilizers the content of P_2O_5 increased more than twice and made 34.6 and 38.7 mg/kg of soil (III class of availability), to the middle of the VI rotation it equaled 56.9--60.1 mg/kg and corresponded to the IV class of phosphorus availability. At the end of VI -- the middle of the VII rotation the content of P_2O_5 in options with fertilizers exceeded its quantity in the control option by 3.6--4.6 times (Tab. 3) due to accumulation of residual unused phosphorus of fertilizers.

Table 2: Content and balance of humus in 0--20 cm layer, %. HCP_{05} -- 0.22 %.

n/n	Year									Balance ± (1948--2015)	
	1948	1970	1979	1986	1991	1996	2007	2011	2015	%	t/ha
1	3.55	3.01	2.80	2.71	2.82	2.75	2.77	2.80	2.78	--0.77	--20.0
2	3.55	3.02	3.04	3.10	3.10	3.07	3.04	3.12	3.14	--0.41	--10.7
3	3.55	3.64	3.65	3.58	3.60	3.68	3.63	3.68	3.69	+0.14	+3.6
4	3.55	2.76	2.61	2.60	2.70	2.72	2.69	2.71	2.73	--0.82	--21.3
5	3.55	2.90	2.78	2.89	2.85	2.80	2.85	3.00	3.04	--0.51	--13.3
6	3.55	3.47	3.20	3.23	3.26	3.24	3.18	3.30	3.28	--0.27	--7.0
7	3.55	2.90	2.78	2.89	3.00	2.95	3.10	3.20	3.18	--0.37	--9.6
8	3.55	3.47	3.20	3.23	3.50	3.58	3.62	3.66	3.65	+0.10	+2.6

The content of exchange potassium in the control option (option 1) over 36 years (1979--2015) changed a little since the available potassium was replenished constantly due to its transition from inaccessible fixed form. As a result of long-term impact of various fertilizer systems the availability of soil with its exchange potassium is different and ranges from III to V class of availability (Tab. 4).

TABLE 3: Change of P_2O_5 content in 0--20 cm layer, mg/kg.

Rotation, year	Option							
	1	2	3	4	5	6	7	8
Initial, 1948	21.4							
III, 1979	15.9	34.6	38.7	15.3	27.6	33.3		
V, 1999	14.3	57.8	59.2	13.0	47.2	52.0	47.4	55.5
VI, 2007	14.0	56.9	60.1	13.3	48.8	53.1	49.6	56.7
VII, 2015	14.7	58.4	61.3	13.5	57.2	54.3	64.5	63.0

TABLE 4: Change of K_2O content in 0--20 cm layer, mg/kg.

Rotation, year	Option							
	1	2	3	4	5	6	7	8
Initial, 1948	273							
III, 1979	253	321	367	268	337	386		
V, 1999	258	232	391	250	359	380	324	387
VI, 2007	255	340	385	244	362	391	383	386
VII, 2015	248	343	411	247	358	430	426	433

In terms of its genetic properties the ordinary carbonate chernozem is quite resistant to acidifying effect of fertilizers. The reaction of soil solution in the studied soil over 66 years of the experiment did not change and was neutral (pH_w -- 6.9--7.2). The application of mineral fertilizer systems had no impact on the total absorbed bases in nonirrigated and irrigated soil. Organomineral fertilizer systems increased the total absorbed bases by 2.3 and 2.4 mg-eq/100 g of soil.

4. Conclusion

The study within the stationary field experiment of 1948 showed that the long-term use of different fertilizer systems in nonirrigated and irrigated conditions created certain levels of soil fertility typical for each agrosystem and defining quantitative and qualitative indicators of crop yield and efficiency of crop rotation.

Agrophysical and water properties of ordinary carbonate chernozem at extensive use of arable land without fertilizers and long irrigation became considerably worse: density increased, porosity and water permeability of soil decreased. The use of fertilizers improved agrophysical and water properties of soil: its density decreased, porosity, structure index, water stability, water permeability and hygroscopicity increased.

Long-term use of mineral and organomineral fertilizers had an impact on content, balance of humus and agrochemical properties of bogara and irrigated soil. The biggest losses of humus and fertilizer elements were defined in options without fertilizers at irrigation and without fertilizers and irrigation. The use of mineral fertilizers reduced humus losses and stabilized its content at different levels smaller than the initial. In bogara conditions the use of the recommended organomineral fertilizer system (manure 8 t/ha + $N_{44}P_{42}K_{24}$) stabilized humus content and its positive balance (+3.6 t/ha). In irrigated conditions the application of estimated organomineral fertilizer system (manure 15 t/ha + $N_{87}P_{36}K_{7}$) since 1986 restored humus content over 11--13 years to the initial level and ensured its further positive balance (+ 2.6 t/ha).

The content of total nitrogen, phosphorus, potassium and reaction of soil solution during the experiment did not change.

Soil availability with labile P_2O_5 became low (1.3--1.5 mg/100 of soil) without fertilizers in bogara and at irrigation. At long-term use of fertilizer systems through VI rotations the P_2O_5 content increased 3.6--4.3 times in comparison with the control option and corresponded to the V class. The content of K_2O during observations in options without fertilizers (without irrigation and at irrigation) corresponded to the III class of availability, at application of mineral and organomineral fertilizer systems -- to the IV class. Only in the VII rotation the availability of soil with potassium at the introduction of organomineral and estimated mineral fertilizers became high.

References

[1] Sychev, V.G. (2000). Trends of agrochemical indicators of soil fertility in the European part of Russia. Moscow: CRIA. 187 p.

[2] Sychev, V.G., Schafran, S.A. (2013). Agrochemical properties of soils and efficiency of mineral fertilizers. Moscow: VNIIA, 296 p.

[3] Aliev, A.M., Sychev, V.G., Vaulina, G.I., Samoylov, L.N. (2013). Scientific bases of complex application of chemicalixation and ecological aspects of intensive agriculture. Moscow: VNIIA. 196 p.

[4] Bizhoev, V.M. (2005). Change of fertility of ordinary chernozem at 50-year use of fertilizers and irrigations. Nalchik: Polygraphy, 199 p.

[5] Prostakov, P.E. (1964). Agronomical characteristics of soils of the North Caucasus, vol. 1. Moscow: Rosselkhozizdat, pp. 11, 16, 100--102.

[6] Methodical instructions on research practice in long experiments with fertilizers, part 1. Moscow, 1975, 167 p.

[7] Methodical instructions on research practice in long experiments with fertilizers. (1983). part 2. Moscow, 171 p.

[8] Agrochemical study methods of soils, ed. 4. (1965). Moscow: Nauka, 436 p.

[9] Methodical study guide of soil structure. (1969). Kolos, 528 p.

[10] Lifanenkova, T.P., Bizhoev, R.V., Bizhoev, M.V. (2011). Monitoring of fertility of ordinary chernozem at long irrigation and application of fertilizer systems in agrolandscape agriculture of Kabardino-Balkaria. Results of long study in the system of Geographical network of experiments with fertilizers in the Russian Federation (devoted to the 70th anniversary of Geonetwork). Moscow, pp. 352--368.

[11] Lifanenkova, T.P., Bizhoev, R.V. (2018). Influence of systematic use of fertilizers in the conditions of bogara and at long irrigation on productivity of cultures, efficiency of grain-grass-hoe crop rotation and fertility of ordinary chernozem in agrolandscape agriculture of Central Ciscaucasia. Agrochemistry, no. 4, pp. 3--17.

[12] Fokin, A.D. (1994). The role of organic matter of soils in natural and agricultural ecosystems. Soil science, no. 4, pp. 40--47.

[13] Shevtsova, L.K. (1998). Humus of chernozems and its change at intensive agricultural use. Fertility of chernozems of Russia. Moscow, pp. 196--225.

[14] Edinger, E. (1980). Aktuelle Problem der landwirtschaftliche. Forschung (Linz), B. 13, pp. 21, 472.

[15] Fleg, W. (1988). Generation of model chemical precurses. Humic substances and their Role in the Envisionvent. Chichegter, A. I, 75 p.

[16] Carter, M.R. (2002). Soil, quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. Agron. J., vol. 94, pp. 38--44.

[17] Korschens, M. (1980). Die Abbangigkeit der organischen Bodensubstanz von Standortfactoren ind acker-und pflanzenbaulichen Massnahmen, ihreBeziehungen zu Bodenei genschaften und Ertrag sowie Ableitung von ersten Bodenfrucht-barkeitske ziffern für den Gehalt des Bodens an organischen Substanz. Berlin: Akad. Landwirtsch. Wiss. DDR. Diss. B., pp. 296.

[18] Zaidelman, F.R., Shvarov, A.P. (2000). Hydrotermic regime, dynamics of organic matter and nitrogen in drained soils at different sanding modes. Archives of Agronomy and Soil science, vol. 45, pp. 123--142.

[19] Zalasiewicz, I., Williams, M., Steffen, W., Crutzen, P. (2010). The New World of the Anthropocene. Environmental Science & Technology, vol. 44(7), pp. 2228--2231.