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Influence of regional technologies of varying intensity on the bioproductivity of sod-podzolic medium loamy soil in the Central region of the Russian Federation

S.M. Viyugin[1,*], A.V. Kuchumov[2], G.V. Viyugina[3], S.E. Terentyev[4] and I.A. Karamulina[1]

[1]Smolensk State Agricultural Academy, Faculty of Engineering and Technology, Department of Agronomy, Land Management and Ecology, 10/2 B. Sovetskaya Str., RU214000 Smolensk, Russia
[2]Smolensk State Agricultural Academy, Faculty of Economics, Department of Production Management, 10/2 B. Sovetskaya Str., RU214000 Smolensk, Russia
[3]Smolensk State University, Faculty of Natural Geography, Department of Biology and Ornamental Crop Production, 4 Przhevalskogo Str., RU214000 Smolensk, Russia
[4]Smolensk State Agricultural Academy, Faculty of Engineering and Technology, Department of Agricultural Processing Technology, 10/2 B. Sovetskaya Str., RU214000 Smolensk, Russia
[*]Correspondence: vyugin_sm@mail.ru

Abstract. This study is oriented to elucidating the role of the basic elements of regional farming systems in soil-crop complex using agricultural technologies of different levels of cultivation of field crops in the Smolensk Region.
As a result of monitoring carried out in 1991–2008 on a reference site located in the Smolensk Region, negative changes of soil profile were revealed. Degree of soil podzolization increased what contributed to its degradation. All genetic horizons demonstrated deterioration in the basic parameters of soil fertility.
Many years of experience showed a significant influence of the elements of studied technologies on soil acidity parameters, on the level of available phosphorus and exchangeable potassium; the amount of humic compounds was, however, characterized by relative stability.
According to the total grain harvest of winter rye, spring soft wheat and barley, as well as of the green mass of perennial and annual herbs, studied variants were ranged in the following order: intensive, organic, adaptive, and extensive. Organic technology is suitable for getting environmentally friendly products.
Obtained results are recommended to be used in the development of regional technologies of various intensity for the bio-productivity of sod-podzolic medium loamy soil in the Central region of the Russian Federation, as well as in regions with similar soil and climatic conditions. Choice of particular variant is in each case determined by the baseline characteristics of soil, planned level of productivity and harvest quality, availability of material and monetary resources in the economy.

Key words: agrochemical soil parameters, agroecological monitoring, soil bio-productivity, sod-podzolic soil, soil profile, regional technologies, organic technology, crops, six-field field grain and grass crop rotation.

INTRODUCTION

Unstructured intensification of agricultural production leads to an unreasonably high anthropogenic load on agrocoenosis.

As a result, the content of mobile compounds of aluminum, manganese, pesticide residues increases in soil, plants, groundwater and water bodies, aa well as large amount of nitrate nitrogen, and other substances that are toxic to soil and plants and negatively affect crop yields and the quality of crop products (Ladonin et al., 1996; Chernikov et al., 2001; Viyugina & Viyugin, 2003; Stehlík, et al., 2019).

The most important task of the emerging multi-structured agriculture in the Central region of Russia is sustainable increase of agricultural productivity. In the context of heightened environmental and socioeconomic problems, it is necessary to revise the main links of existing farming systems with a view to adapting them to local soil and climatic conditions (Kiryushin, 2011).

The low natural fertility potential of sod and podzolic soils causes the need for intensive development of the agricultural industry with extensive use of chemical and modern treatments of soil (Bahirev, 2016).

However, it is possible to increase the rate of production of high quality agricultural products in the current environment only with the transition to environmentally sound and economically sound systems of fertilizers and pesticides application, providing in addition to high yields extended reproduction of soil fertility and sustainable state of agrocenoses (Kiryushin & Kiryushin, 2015).

In developing regional farming systems, it is necessary to take into account the fact that the interaction between components of agrocenosis should be optimal and not limit potential yields of agricultural crops (Bahirev, 2016; Cherkasov, 2016).

To eliminate negative environmental consequences, with a view to the sustainable development of agricultural production in Russia, a number of scientists have developed scientifically based methodological principles for the design of adaptive landscape farming systems that can improve environmental sustainability of agricultural landscapes, stabilize fertility reproduction and prevent soil degradation, and optimize soil processing system due to its minimization (Kashtanov et al., 1994; Kiryushin, 2011; Viyugin & Viyugina, 2014).

Currently in the Russian Federation, there is official law No. 280-FZ dated August 3, 2018 'On Organic Production and Amendments to Certain Legislative Acts of the Russian Federation' that includes Article 8 'Transition to Organic Agriculture and Organic Production'. The Federal Law on organic agriculture states that the technology of cultivating organic products allows obtaining eco-friendly agricultural products, raw materials and food. In this regard, developing technologies for organic crop cultivation is relevant. Under present-day conditions, organic agricultural production will contribute to solving a large number of problems, since this method provides for an almost complete rejection of mineral fertilizers, pesticides and genetically modified organisms (Akimova & Polushkina, 2015).

The relevance of the long-term experimental studies is that in the modern economic and social situation taking into account environmental contradictions in the Russian Federation, including the Central region of Russia, detailed adaptation of agriculture to multi-level production relations under different soil-climatic conditions is required, when earlier developed methods of farming systems construction do not fully meet the demands of producers.

In this regard, a new methodical approach is relevant in the development and construction of highly effective balanced technologies of crops cultivation in agricultural systems of different intensity determined by different level of material, technical and financial situation of a particular commodity producer in the conditions of the Central region of the Non-Chernozem Zone of the Russian Federation.

The scientific novelty of the multi-year study is that experimental data obtained over 18 years in three rotations of six-field grain and herb crop rotation allowed to study dynamics of the main agrochemical indicators of sod and podzolic soil fertility and productivity of grain and herb crop rotation under the influence of different modifications of regional cultivation technologies of field crops, which are characteristic to farming systems of varying intensity in the conditions of the Central region of the Non - Chernozem Zone of the Russian Federation. The obtained results of the research are recommended to be used in the development of specific regional technologies of crops cultivation on sod-podzolic medium-clay soil in the Central region of the Russian Federation taking into account the initial characteristics of the soil, the planned level of yield and its quality, the availability of material and monetary resources in the economy.

Forecasting optimal land use conditions in agricultural production with the goal of sustainable and cost-effective increase in the fertility of sod-podzolic soils with minimal risks for ecological condition and ecological functions of soils is possible only under the conditions of many years of stationary field experiments laid down in compliance with the basic rules of field experiment methodology (Shatilov, 2001; Shamanaev et al., 2006; Hospodarenko et al., 2018).

OBJECTS AND METHODS

To carry out monitoring studies and the subsequent laying of stationary experiment in 1991, a land plot was selected in the third field of the six-field crop rotation field of Smolensk Agricultural Experimental Agricultural Institute. Results of test sowing and the subsequent accounting of barley crop by working plots showed that the variations in grain yield in repeated plots was insignificant, so this indicates its agrochemical and agrophysical homogeneity.

Before laying a field multifactor experiment for a detailed study of the territorial variability of fertility of sod-podzolic medium loamy soil on July 25, 1991, profile 1 was laid on the reference site. The profile is located at a border check irrigation of the field multifactorial experiment with the extensive variant of agricultural cultivation where no mineral and organic fertilizers or chemical plant protection products against weeds, pests and diseases are provided. In 2008, profile 1a located near profile 1 made in 1991 was laid on the reference site.

Based on the long-term stationary field experience of the Smolensk State Agricultural Academy from 1991 to 2008, agroecological monitoring studies were carried out to study the effect of various modifications of regional technologies for cultivating crops in agricultural systems of varying intensity on the fertility of sod-podzolic soil and the productivity of grain-crop rotation in the conditions of the Central region of the Non-Black Earth Zone of the Russian Federation.

Experimental design included four modifications of regional crop cultivation technologies.

1. Extensive technology – according to experimental scheme, no mineral or organic fertilizers, as well as pesticides were applied. Preparation system included 10–12 cm afterharvesting tillage; 20–22 cm moldboard plowing; early spring harrowing, and 10–12 cm pre-sowing cultivation. Sowing was carried out with a seeding rate established by the number of germinating seeds.

2. Adaptive technology – N55P45K45 kg of AI ha^{-1} were applied in the rotation on average per 1 hectare. Pesticides were added based on average recommended doses. Preparation system included 10–12 cm afterharvesting tillage; 20–22 cm autumn plowing in combination with subsoiling of 32–35 cm; early spring harrowing, and pre-sowing cultivation. Seed was treated with the average dose of fungicide, and weight sowing rate was determined by the number of germinating seeds.

3. Intensive technology – average annual dose of mineral fertilizers was N85P75K75 kg of AI ha^{-1}. Pesticides were added based on maximum recommended doses. Preparation system included 10–12 cm afterharvesting tillage; 35 cm deep nonmoldboard loosening using chisel plow and 10–12 cm disking; early spring harrowing, 10–12 cm complete cultivation, and 8–10 cm pre-sowing cultivation. The seed was treated with the maximum possible dose of fungicide against diseases, and weight sowing rate was determined by the number of germinating seeds.

4. Organic technology – average annual dose of organic fertilizers was 12 t ha^{-1}. Preparation system included 10–12 cm afterharvesting tillage; 20–22 cm autumn plowing; early spring harrowing and 10–12 cm pre-sowing cultivation. According to this technology, heating of seeds with hot air was carried out before sowing. Weight sowing rate was determined by the number of germinating seeds. Agrotechnical methods and biological techniques were used for regulating the phytosanitary state of crops. This technology is designed to produce environmentally friendly products for baby and diet food.

In addition to the methods studied, agrotechnical methods of crop cultivation were common for the Central region of the Non-Chernozem Zone of the Russian Federation, including the Smolensk Region.

In this experiment, varieties cultivated were in the State Register of Breeding Achievements Approved for Use in the Central Region of the Non-Black Earth Zone of the Russian Federation.

In this experiment, nitrophoska, ammonium nitrate, double superphosphate and 60% potassium salt and well-rotted cattle manure were used.

A multifactor field stationary experiment was laid down by split-plot method in 4 repetitions, on sod-medium loamy soil formed on cover loam, with arable horizon thickness of 20–22 cm. Area of an accounting plot was 44 m^2 (5.5×8 m). Soil samples were taken from the arable layer (20–22 cm) at the end of the first, second and third rotation during six-field crop rotation. Samples for analysis were taken from two non-adjacent repetitions from 30 points followed by the formation of a mixed sample for each variant of the experiment. Sample size was determined by E.A. Dmitriev (Dmitriev, 1995; Kiryushin, 2011).

Baseline agrochemical parameters of soil in field experiment were as follows: humus – 1.96%; pH_{ac} – 6.2; Ha – 2.8 cmol kg^{-1} of soil; S – 15 cmol kg^{-1} of soil; mobile phosphorus –177 mg kg^{-1} of soil, mobile potassium – 220 mg kg^{-1} of soil.

The pattern of crop rotation for this experiment was as follows:

1.Vetch-oatmeal mix for green fodder. 2. Winter rye. 3. Barley with undersowing of clover-timothy mix. 4. Clover-timothy mix of 1 year of use. 5. Clover-timothy mix of 2 years of use. 6. Spring wheat

The studies were carried out according to the following methods: humus – according to Tyurin in the modification by Central Research Institute of Agrochemical Services [GOST 26113-91]; pH_{KCl} – potentiometrically (GOST 26487-85); mobile phosphorus and potassium – according to Kirsanov [GOST 26207-93]; amount of absorbed bases – according to Kappen-Gilkovits; Kappen hydrolytic acidity in the modification by Central Research Institute of Agrochemical Services (GOST 26212-91). To analyze experimental data, we calculated statistical parameters of samples with quantitative variability of trait and used analysis-of-variance method (Dmitriev, 1995; Dospekhov, 1985; Akimova & Polushkina, 2015).

RESULTS AND DISCUSSION

Before laying a field multifactor experiment, profile 1 was laid for monitoring the patterns of territorial variability of fertility of sod-podzolic medium loamy soil in the reference area.

The following is a description of the morphological features of the genetic horizons of the soil profile 1 started in 1991.

A_p 0–22 is an arable layer, dark gray with a slightly brown hue, loose, penetrated by worms channels and plant roots, there are semi-decomposed parts of root system, lumpy-granular structure is relatively strong, moist, medium loamy with gradual transition to A_1A_2 horizon.

A_1A_2 22–38 is a transitional humus-eluvial, yellow-brown layer, of cloddy-nutty structure, with large number of roots and worm channels, compacted, moist, transition to A_2B horizon is smooth.

A_2B 38–74 is a transitional eluvial-illuvial horizon, yellowish-brown with bright flashes, of weak nutty structure, dense, with rare roots, moist, transition to horizon B is gradual.

B 74–98 is an illuvial horizon, yellow-brown, moist, densified, medium loamy, transition to horizon C is clear.

C 98–155 is a mother rock: clay loam mantle, yellowish-brown, very dense, moist.

Nomenclature of soil according to the 1977 classification is sod-podzolic, slightly podzolized, medium loamy soil on clay loam mantle (Umbric ALBLUVISOKS) (Egorov et al., 1977; Jørgensen, 2014; Naumov, 2016).

In 2008, laying down of the second 1a profile located near profile 1 was carried out. Repeated study of soil profile after 18 years of monitoring studies made it possible to trace changes in the composition and properties of soil at the polygon during many years of stationary field experiment.

Over specified period, the thickness of arable horizon decreased by 2 cm and, accordingly, the thickness of A_1A_2 and A_2B horizons increased what increased the degree of soil podzolization and contributed to its degradation.

The following is a description of the morphological features of genetic horizons in 2008.

A_p 0–20 is an arable horizon, gray with a brown hue, moist, dense, densely penetrated by plant roots and worm channels, of cloddy-lumpy-dusty structure, medium loamy with a gradual transition to A_1A_2 horizon.

A_1A_2 20–40 is a transitional humus-eluvial horizon, pale-whitish in color, of cloddy-nutty structure, with worm channels and roots, compacted, moist, transition to A_2B is gradual.

A_2B 40–76 is a transitional eluvial-illuvial horizon, yellowish-brown with flashes, grayish-whitish powdering of tongued form, of cloddy-nutty structure, dense, moist, root channels are visible, transition to horizon B is gradual.

B 76–96 is an illuvial horizon, yellowish-brown, moist, very dense, medium loamy, transition to the mother rock is clear.

C 96–156 is a mother rock: clay loam mantle, yellowish-brown, very dense, moist.

Nomenclature of soil according to profile No. 1a according to the 1977 classification is sod-podzolic, medium-podzolic, medium loamy soil on clay loam mantle.

A comparative analysis of the dynamics of changes in the agrochemical properties of the genetic horizons of soil profile in 2008 (profile 1a) compared with 1991 (section 1) is shown in Table 1.

Table 1. Agrochemical parameters of the genetic horizons of sod-podzolic medium loamy soil, profile 1a, 2008

Parameters	A_p 0–20 cm		A_1A_2 20–40 cm		A_2B 40–76 cm		B 76–96 cm		C 96–156 cm	
	2008	± to 1991	2008	± to 1991	2008	± to 1991	2008	± to 1991	2008	± to 1991
Humus, %	1.82	-0.20	1.27	0.31	0.50	-0.33	0.27	-0.25	0.21	-
pH_{KCl}	5.57	-0.63	5.37	-0.63	3.39	-0.95	3.18	-1.05	4.13	-0.49
Ha, cmol kg^{-1} of soil	3.04	-0.18	2.52	-0.21	2.95	-0.29	2.62	-0.35	2.95	-0.28
S, cmol kg^{-1} of soil	14.0	-0.8	11.1	-1.0	10.1	-1.2	8.7	-1.4	11.7	-1.1
V, %	82.2	-4.3	81.5	-5.7	77.4	-6.7	76.9	-9.3	79.9	-8.8
$P_2O_{5\ mg\ kg^{-1}}$	102	-70	97	-48	84	-36	50	-35	40	-23
K_2O, mg kg^{-1}	90	-30	104	-38	52	-42	41	-34	27	-16

In 2008, humus content in A_p horizon decreased by 9.9%, in A_1A_2 horizon – by 19.6%, in A_2B horizon – by 37.1%, and in horizon B – by 48.1%. Absolute reserves of humus calculated taking into account the thickness of genetic horizons and their density decreased similarly.

Judging by pH_{KCl} value, exchange acidity in A_p horizon increased with the depth along the soil profile by 10.2%, in A_1A_2 horizon – by 8.3%, in A_2B horizon – by 21.9%, and in B horizon – by 24.8%.

In 2008, hydrolytic acidity in horizon A_p increased in comparison with 1991 by 6.2%, in horizon A_1A_2 – by 8.3%, in horizon A_2B – by 9.8%, and in horizon B – by 13.4%. Amount of absorbed bases decreased with the depth of profile from 14.0 to

8.7 cmol kg^{-1} of soil and the degree of soil saturation with bases – from 82.2 to 76.9%.

The content of mobile forms of phosphorus in arable horizon decreased from 172 to 102 mg kg^{-1}, or by 40.7%, in A_1A_2 – by 33.1%, in A_2B – by 30%, in horizon B – by 41.1%. In a similar way, the content of exchange potassium changed along the soil profile.

Summarizing the abovementioned, it should be noted that the deterioration of agrochemical parameters of soil fertility at the monitoring polygon during 18 years of observation is due primarily to the fact that the cultivation of crops was carried out according to extensive technology (variant 1).

The basis of further monitoring studies, from the moment of start in 1991 and up to 2008, was a long-term stationary multi-factorial field experiment of the Smolensk State Agricultural Academy.

Experimental data obtained over 18 years of research in three rotations of a six-field grain-grass crop rotation made it possible to study dynamic changes in basic agrochemical parameters of the fertility of sod-podzolic soil and the productivity of a grain-grass crop rotation under the influence of various modifications of regional cultivation technologies for field crops that are typical for farming systems of varying intensity in the conditions of the Central Region of the Non-Black Earth Zone of the Russian Federation.

Modifications of regional technologies studied in this experiment, with different types and doses of added fertilizers, had an different effect on the soil acidity of arable horizon. Results of these studies in arable horizon are summarized in Table 2. In the variant with extensive technology where no mineral fertilizers are provided, a maximum acidification of a soil solution was specified: for the first rotation by 10.1%, for the second – by 12.4%, and for the third – by 14.2% compared to baseline data.

Table 2. Influence of the modifications of regional technologies on the physicochemical properties of arable horizon of sod-podzolic medium loamy soil

Technologies	Rotation I 1991–1996			Rotation II 1997–2002			Rotation III 2003–2008		
	pH_{KCl}	Cmol kg^{-1} of soil		pH_{KCl}	Cmol kg^{-1} of soil		pH_{KCl}	Cmol kg^{-1} of soil	
		H_a	S		H_a	S		H_a	S
1.	5.57 ± 0.12*	3.0 ± 0.05	14.0 ± 1.1	5.43 ± 0.11	3.2 ± 0.04	13.8 ± 0.9	5.32 ± 0.09	3.4 ± 0.03	13.0 ± 0.8
2.	5.83 ± 0.11	2.7 ± 0.03	15.8 ± 1.3	5.76 ± 0.10	2.5 ± 0.02	16.6 ± 1.4	5.73 ± 0.11	2.3 ± 0.01	17.4 ± 1.4
3.	5.79 ± 0.11	2.4 ± 0.04	17.3 ± 1.5	5.70 ± 0.9	2.2 ± 0.01	18.9 ± 1.6	5.61 ± 0.10	2.0 ± 0.09	20.2 ± 1.8
4.	6.39 ± 0.14	2.2 ± 0.02	19.0 ± 1.7	6.63 ± 0.13	2.0 ± 0.01	24.0 ± 1.9	6.72 ± 0.14	1.8 ± 0.08	26.0 ± 2.1

Note: 1 – extensive; 2 – adaptive; 3 – intensive; 4 – organic; * arithmetic mean error.

Low doses of mineral fertilizers added under crops using adaptive technology contributed to a slight increase in the acidity of soil solution, by crop rotations, respectively: 5.9%, 7.1%, and 7.6%.

Adding increased doses of mineral fertilizers when cultivating crops using intensive technology increased the acidity of soil solution, by crop rotations, respectively: 0.41 units pH_{KCl} (7.1%); 0.50 units pH_{KCl} (8.1%); 0.59 units pH_{KCl} (9.5%). Organic technology including cattle manure as the main fertilizer contributed to a fairly intensive neutralization of soil solution. The value of pH_{KCl} was increased, by crop rotations, respectively: +0.19 units pH_{KCl} (3.1%); +0.43 units pH_{KCl} (6.9%); +0.52 units pH_{KCl} (8.4%).

Hydrolytic acidity of the soil, against an extensive background without fertilizing, increased compared to baseline by 7.1; 14.3 and 21.4% according to crop rotation. When cultivating crops using adaptive technology, parameters of hydrolytic acidity decreased, by crop rotations, by 3.6; 10.7; 17.9%, using intensive technology – by 14.3, 21.4, and 28.6%, respectively.

The most prominent parameters for optimizing soil fertility were noted with using organic technology where the improvement in hydrolytic acidity compared to the extensive technology was, by crop rotations: 21.4, 28.6, and 35.7%.

The data on the influence of different technologies on the amount of absorbed bases are of real interest. Maximum decrease in the amount of absorbed bases compared to the baseline was noted in the arable layer during using extensive technology, respectively, by: 1.0 (3.1%), 1.2 (3.1%), 2.0 (3.1%) cmol kg^{-1} of soil.

Using mineral fertilizers in adaptive technology has led to an increase in the amount of absorbed bases in the arable horizon, by crop rotations, respectively: + 0.8, + 1.6, + 2.4 cmol kg^{-1} of soil. Higher rates of the enrichment of arable horizon with absorbed bases were noted in the variant with intensive technology, by crop rotations, respectively: + 2.3, + 3.9, + 5.2 cmol kg^{-1} of soil.

Regular adding of manure provided by organic technology ensured a substantial increase in the amount of absorbed bases in arable layer, by crop rotations, by: 4.0, + 9.0, + 11.0 cmol kg^{-1} of soil. When adding manure under winter crops, an increase in the amount of absorbed bases in the arable layer was revealed. Therefore, using manure for sod-podzolic soils contributes to the fixation and accumulation of calcium and magnesium in arable layer.

Thus, under the conditions of long-term stationary field experiment, the modifications of regional technology are arranged in the following order according to the degree of influence on the cation exchange properties of soil: extensive, adaptive, intensive, organic. Summarizing the results obtained, it should be noted that soil cultivation with periodic adding of manure and mineral fertilizers in various doses, during three phases of crop rotation, improved the physical and chemical parameters of sod-podzolic soil studied in the course of this experiment.

Dynamic changes in soil humus can demonstrate the effectiveness of technologies used for cultivating crops (Ladonin et al., 1996; Antille et al., 2019).

Table 3 shows the experimental data on the changes in humus content with different modifications of regional technologies during the experiment.

With extensive technology (control variant), there was a sharp decrease in humus in arable layer during the first phase of crop rotation by 0.2%, during the second – by 0.24%, and during the third – by 0.29%. That is, extensive use of soil without adding organic substances and with low yields by crop rotations resulted in intensive degradation of arable horizon.

When adding different doses of mineral fertilizers, there was also a slight decrease in humus content in arable horizon from the baseline (1.96%), by crop rotation with adaptive technology, respectively: by 0.17, 0.13, and 0.07%; with intensive technology – by 0.13, 0.07, and 0.02%. At the same time, adaptive and intensive technologies, during the third rotation as compared with the first one, demonstrated relatively low rates of humus accumulation (0.10 and 0.11%) due to an increase in crop yield and, accordingly, an increase in the number of incoming crop and root residues participating in humification processes.

On an organic background, humus is replenished. During the first rotation the increase in humus content was 0.02%, during the second rotation – 0.11%, and during the third rotation this value was 0.15%.

According to the data in Table 3, during three rotations in the variant with extensive technology where no fertilizers were provided by the experimental scheme, the content of mobile forms of phosphorus decreased: for rotation I – by 7 mg kg^{-1}, for rotation II – by 12 mg kg^{-1}, and for rotation III – by 18 mg kg^{-1}. Adding different doses of mineral fertilizers and manure contributed to a different replenishment of the reserves of mobile phosphorus in arable layer.

Table 3. Influence of the modifications of regional technologies on soil fertility parameters of the arable horizon of sod-podzolic medium loamy soil

Technologies	Rotation I 1991–1996			Rotation II 1997–2002			Rotation III 2003–2008		
	Humus, %	mg kg^{-1} of soil		Humus, %	mg kg^{-1} of soil		Humus, %	mg kg^{-1} of soil	
		P_2O_5	K_2O		P_2O_5	K_2O		P_2O_5	K_2O
1.	1.76 ± 0.02*	170 ± 7.5	207 ± 8.6	1.72 ± 0.03	165 ± 6.6	201 ± 7.8	1.67 ± 0.01	159 ± 5.3	195 ± 8.4
2.	1.79 ± 0.02	187 ± 8.2	239 ± 9.2	1.83 ± 0.05	198 ± 8.9	247 ± 8.2	1.89 ± 0.04	204 ± 8.9	252 ± 8.6
3.	1.83 ± 0.04	205 ± 9.4	257 ± 8.9	1.89 ± 0.05	222 ± 9.7	276 ± 9.2	1.94 ± 0.05	229 ± 7.7	284 ± 9.4
4.	1.98 ± 0.05	181 ± 8.0	229 ± 7.9	2.07 ± 0.08	189 ± 8.3	238 ± 7.9	2.11 ± 0.09	195 ± 8.8	247 ± 8.1

Note: 1 – extensive; 2 – adaptive; 3 – intensive; 4 – organic; * arithmetic mean error.

Obtained experimental data showed that the rate of accumulation of mobile forms of phosphorus was directly dependent on the modification of regional technology.

So, if adaptive technology demonstrated increasing content of mobile phosphorus during first rotation by 10 mg kg^{-1}, during second rotation – by 21 mg kg^{-1} and, finally, during third rotation – by 27 mg kg^{-1}, then with intensive technology the accumulation of mobile phosphorus increased by three rotations, respectively, by 28, 45 and 52 mg kg^{-1}.

When using organic technology, the rate of accumulation of mobile phosphorus by crop rotations was: 4, 12 and 18 mg kg^{-1} of soil.

Data in Table 3 show significantly different at $p < 0.05$ values of mobile potassium content depending on the technology. Extensive technology demonstrated a decrease in mobile potassium of arable layer, by crop rotations, by: 13, 19 and 25 mg ha^{-1}.

Variant with adaptive technology showed an increase in mobile potassium in comparison with the baseline, by crop rotations, by: 19, 27 and 32 mg ha^{-1}.

Maximum content of mobile potassium in arable horizon was noted against the intensive background. The increase in mobile potassium in the first rotation was 37 mg kg^{-1}, in the second rotation – 56 mg kg^{-1}, and in the third rotation – 64 mg kg^{-1}.

Against the organic background, an increase in potassium content was also visible but the intensity of mobile potassium accumulation was much lower in comparison with technologies where adding of mineral fertilizers was provided.

Crop yield formation is determined by the level of agricultural crop cultivation technologies applied.

Crop yield data by rotations are shown in Table 4.

When cultivating crops using extensive technology, crop rotation yields amounted to: rotation I – 12.3; rotation II – 13.1; rotation III – 13.9 thousand of grain units. A certain increase in crop yields by crop rotations with extensive technology was mainly due to the implementation of new varieties, improvement of technological operations and improving the quality of their implementation.

Growth of crop productivity with adaptive technology in comparison with the extensive one, by crop rotations, was: 4.5, 4.6 and 6.1 thousand of grain units with LSD_{05} equal to 1.1, 1.0 and 1.4 thousand of grain units, respectively.

Table 4. Total crop productivity by crop rotation, tons of grain units

Modifications of regional technologies	Rotation I 1991–1996	Rotation II 1997–2002	Rotation III 2003–2008
Extensive	12.3	13.1	13.9
Adaptive	16.8	17.7	20.0
Intensive	19.2	20.6	22.5
Organic	17.9	19.2	20.2
LSD_{05}	1.1	1.0	1.4

Maximum increase in crop yields was noted for intensive regional technology in comparison with extensive technology, by crop rotations: 6.9, 7.5 and 8.6 thousand of grain units. A similar increase in crop yields was due to improved agrochemical parameters of soil fertility caused by the investment of additional material and financial resources.

Productivity of arable land with using organic technology compared with the extensive one increased by: 5.6, 6.1 and 6.3 thousand of grain units.

The Smolensk Region is well-placed to at least double the output of such products for delivering them for the production of baby food, dietary nutrition for health centers, hospitals, retirement homes, to the industrially developed regions of Russia, as well as to Western countries where producing eco-friendly products is hindered due to industrialization.

CONCLUSION

1. As a result of monitoring conducted on the reference site in 1991–2008, negative changes in soil profile were obvious. The degree of soil podzolization increased what contributed to its degradation. All genetic horizons of the reference site demonstrated the processes of deterioration of the basic parameters of soil fertility.

Deterioration of agrochemical parameters of soil fertility in the reference site during 18 years of observation was due primarily to the fact that the cultivation of crops was carried out according to extensive technology (variant 1).

2. Modifications of regional technologies studied in this experiment have different effect on the dynamic changes in agrochemical parameters of the fertility of arable horizon. Extensive technology led to the acidification of soil solution during the first rotation by 10.1%, during the second – by 12.4%, and during the third – by 14.2%.

Adding mineral fertilizers in different doses that was provided for the cultivation of crops within adaptive and intensive technologies contributed to different increase in the acidity of soil solution by crop rotations. Organic technology with cattle manure as the basic fertilizer contributed to the moderate neutralization of soil solution. $pH_{.KCl}$ increased by crop rotations, respectively, by: 3.1%, 6.9% and 8.4%.

Obtained experimental data revealed that higher rates of accumulation of mobile phosphorus were typical for intensive technology, these values were slightly lower when using adaptive technology.

Organic technology resulted in the following rate of accumulation of mobile phosphorus, by crop rotations: 4, 12 and 18 mg kg^{-1} of soil. Similar dynamics was noted for changes in the content of mobile potassium.

3. Maximum productivity of crops during three rotations of a six-field crop rotation on sod-podzolic medium loamy soil was associated with intensive technology. According to our data, organic technology is recommended for getting environmentally friendly products in the production of baby and diet food.

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