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Original Article

The influence of agrotechnologies of organic farming on the content of humus, phosphorus and potassium in the soil

A influência das agrotecnologias da agricultura orgânica no teor de húmus, fósforo e potássio do solo

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Abstract

Organic agriculture is becoming an increasingly popular direction in modern agriculture. At the same time, some researchers and practitioners still have doubts about the ability of this technology to maintain the balance of nutrients in the soil. The article is a contribution to the study of the influence of long-term organic farming on agrochemical soil parameters. The aim of the study was to study the influence of organic farming technology on the content of humus, mobile forms of potassium and mobile forms of phosphorus in the soil of the most important components for fertility – humus, mobile forms of potassium and mobile forms of phosphorus in the non-carbonate chernozems of Western Siberia. The chernozems of Western Siberia are characterized by a high content of humus and nutrients, have optimal properties for agricultural crops. A statistically processed comparison of the quantitative content of humus, mobile forms of potassium and mobile forms of phosphorus in fields with long-term use of organic farming technology, and in similar fields where this technology was not used, was carried out. The article includes a brief geographical, geological, climatic characteristics of the place of the experiment, a description of the applied agricultural technologies and fertilizers. As a result, it was found that the use of organic farming technology has a positive effect on the state of soils, which is confirmed by an increase in the content of humus, mobile forms of potassium and mobile forms of phosphorus.

Keywords: organic farming, soil-saving technologies, content of humus, mobile forms of potassium and phosphorus in the soil.

Resumo

A agricultura orgânica está se tornando cada vez mais comum na agricultura moderna. No entanto, alguns pesquisadores e profissionais ainda têm dúvidas sobre a capacidade desta tecnologia para manter o equilíbrio de nutrientes no solo. O presente artigo é uma contribuição para o estudo do impacto da agricultura orgânica a longo prazo nos indicadores agroquímicos do solo. O objetivo do estudo foi analisar a influência da tecnologia da agricultura orgânica no conteúdo do solo dos componentes mais importantes para a fertilidade – húmus, formas móveis de potássio e formas móveis de fósforo – em solos negros não carbonatos da Sibéria Ocidental. Os "chernozems" da Sibéria ocidental são caracterizados por um alto teor de húmus e nutrientes, possuem propriedades ideais para as culturas agrícolas. Uma comparação estatisticamente processada foi realizada para mensurar a quantidade de húmus, formas móveis de potássio e formas móveis de fósforo em campos com aplicação a longo prazo da tecnologia agrícola orgânica e em campos similares, onde essa tecnologia não foi aplicada. O artigo inclui uma breve descrição geográfica, geológica e climática do local da experiência, uma descrição das tecnologias agrícolas e fertilizantes utilizados. Como resultado, verificou-se que o uso da tecnologia de agricultura orgânica tem um efeito positivo sobre o estado do solo, o que é confirmado pelo aumento do teor de húmus, formas móveis de potássio e formas móveis de fósforo.

Palavras-chave: agricultura orgânica, tecnologias de economia de solo, conteúdo de húmus, formas móveis de potássio e fósforo no solo.

1. Introduction

Organic farming is currently an intensively discussed and developed area of agricultural technologies (Belopukhov et al., 2021; Hazarika et al., 2013; Behera et al., 2012). Discussions are being held in scientific and public circles, documents are being developed, technology is being tested in practice, marketing programs are working. Serious practical experience has been accumulated in many countries of the world. Russia is somewhat lagging behind other countries in this direction, but the vector of direction has been set and there is development.

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It is worth noting that according to the results of foreign studies, when using organic fertilizers, the relative content of nitrogen and potassium forms available to plants increases. As an example, similar results are given in an article by Fan et al. (2023). According to their results, the application of organic fertilizers in comparison with the pure use of chemical fertilizers allows to increase yields by 3.48%, on acidic soils the yield increases by 7.98%, on neutral soils it increases by 3.35%, the content of organic components - by 24.43%, total nitrogen - by 32.79%, total phosphorus - by 23.97%, total potassium - by 44.91%, mobile phosphorus - by 14.46%, mobile potassium - by 16.21%, soil bacteria - by 5.94%, urease - by 22.32%, catalase - by 17.68%.

When conducting scientific research on changes in the humus content in the soil before and after the introduction of the organic component, it was noticed that this indicator increased significantly (Elkhlifi et al., 2023). Similar results are given in the article by Butkevičienė et al. (2023). According to the data obtained by her, the humus content in the soil remained fairly stable or decreased slightly with the preservation of straw and the use of single-component organic biostimulants Azofix, Ruinex and Penergetic. On the contrary, when combining continuous straw application with two- or three-component mixtures of these biological products or with compensatory nitrogen, the humus content increased. Compared with the initial state, this characteristic increased by 1.4–12.8% due to the complication of conditions for the formation of microbiological biodiversity.

Organic farming as an idea attracts a lot of people. But also, the idea of organic farming has opponents, their arguments make you think. First of all, many practitioners and theorists doubt the ability of organic technology to ensure the return of nutrients to the soil (Connor, 2008; Dmitrevskaya et al., 2022). Will the technology designed to improve fertility, on the contrary, lead to exhaustion? Currently, there are farms in Russia that have been practicing organic farming for quite a long time, which makes it possible to assess the impact of this technology on soil fertility. Similar studies have already been conducted. For example, a study of the impact of organic farming (for 11 years) on the state of soils in the Crimea (Belopukhov et al., 2021). But in order to make reliable conclusions, multiple studies conducted in different climatic zones, on different types of soils, with a detailed study of the initial state of the soil and the agricultural techniques used, are necessary. We got acquainted with the experience of using organic farming technology in one of the agricultural enterprises located in Western Siberia. The owners of the farm are confident in the positive impact of organic farming on the condition of the soil, within 8 years of using organic technology, the condition of the soil and crop yields have improved. Quantitative studies were required to confirm this hypothesis.

The purpose of the study: to establish the influence of organic farming technology on the content of the most important components for fertility in the soil – humus, mobile forms of potassium and mobile forms of phosphorus in non-carbonate chernozems of Western Siberia.

2. Objects and Methods of Research

The soil for analysis was taken in an experimental farm, where organic farming technology was practiced for 8 years. The farm is located in the Omsk district of the Omsk region (Figure 1).

To conduct the study, we took soil samples from eight fields in fourfold repetition, the total value of the selected points is thirty-two. Sixteen of them are localized in four fields where organic farming technology with organic fertilizers has been used for 8 years (Fields 5- 8), the remaining sixteen are as control fields, in four fields (Fields 1-4) where the land has not been cultivated for 8 years, organic and mineral fertilizers have not been used, and the soil it has a composition that would be in the prototypes in the absence of organic farming agrotechnics.

Fields 1 and 5, 2 and 6, 3 and 7, 4 and 8 are similar in primary agrochemical composition, so a correlation was carried out between them.

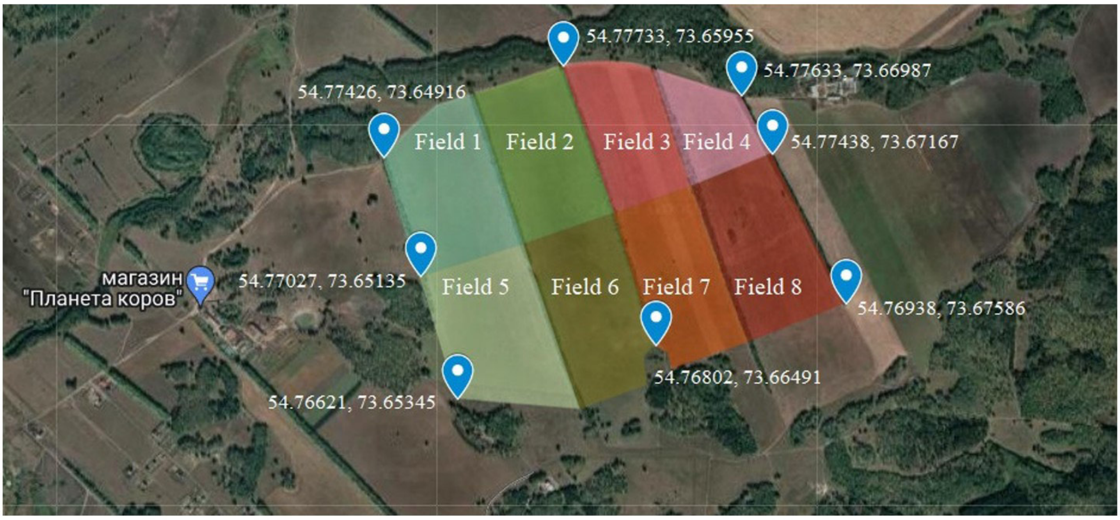

Figure 1. Map of the studied fields.

Earlier (before the start of the organic farming program in this farm, it was more than 8 years ago), control and experimental fields were used the same way for several decades – cereals and vegetable crops were grown there using traditional intensive technology. This led to the depletion of the fertile horizon. At the time of the beginning of the transition of part of the fields (experimental) to organic farming technology, the soil condition was poor (depletion of nutrients, erosion phenomena). The control and experimental fields are located in close proximity to each other. In this connection, they have the same composition as the prototypes would have in the absence of organic farming agrotechnics.

The sampling method consisted in collecting soil samples of the A horizon (0-15 cm) and completely destructuring it. After the destruction of soil samples to smaller aggregates, its study was started on the content of humus, mobile forms of potassium and phosphorus.

The analysis was carried out in the educational and scientific center for collective use - the Service Laboratory of Complex Analysis of Chemical Compounds of the Russian State Agrarian University– Moscow Timiryazev Agricultural Academy.

Humus was determined in accordance with the state standard / method of state standard 26213-91 “Determination of organic matter by the Tyurin method in the modification of CINAO” (Derzhavin et al., 1991b).

To study the mobile forms of phosphorus and potassium, the state standard / state standard 26205 “Determination of mobile forms of phosphorus and potassium by the method of B.P. Machigin in the modification of CINAO” was used using the methods of spectrophotometry and flame photometry (Derzhavin et al., 1991a).

Statistical data processing was carried out in accordance with the two-factor analysis methodology with repetitions in Excel generally accepted in experimental agriculture (Matematicus.ru, 2019).

2.1. Geographical characteristics of the venue of the experiment

The territory of the enterprise is located in the Omsk region, 30 km from Omsk, near the village of Ust-Zaostrovka. The farm is located on the Ishim plain, in the floodplain terrace of the Irtysh River. The territory is flat, formed by sands and clays of Neogene age, overlain by a cover of loess-like loam. The Irtysh riverbed took part in the genesis of the territory, which is due to its instability. The territory is bounded from the east by the Badab lowland, from the south by the Kazakh hills. To the west of the Irtysh River there are many gullies blocking sand deposits from the territory of Kazakhstan.

2.2. Geological characteristics

It is located on the Epigercine plate, namely on the West Siberian plate.

2.3. Soil-geographical zoning

The territory is located in the subboreal climatic zone, in the chernozem region. The soils are composed of ancient alluvial deposits. The parent rock is loess-like loam. The main type of soil is ordinary chernozem. According to the granulometric composition, the soil is slightly loamy. There is a high content of sand fraction in the territory where the application of organic fertilizer has not been carried out. Depending on the type of farming, namely the frequency of use of organic fertilizers, the arable horizon has a different structure. On the territory of the farm, located closer to Ust-Zaostrovka, the texture is closer to sandy loam, in more remote areas light loam.

2.4. Agrochemical assessment of the soil

According to previously conducted studies in ordinary chernozem in the A horizon (0-15-17 cm), the approximate content of exchangeable phosphorus is 200-223 (mg/kg of soil), exchangeable potassium is 100-110 (mg/kg of soil), the content of alkaline hydrolyzable nitrogen is 167-203 (mg/kg of soil) (Sycheva et al., 2013).

2.5. Climatic characteristics

The climate is continental. It is characterized by frosty winter (average January temperature -16 °C) and hot summer (average July temperature +20

°C). The average annual temperature is +2.1 °C. The average annual precipitation is 415 mm. The humidity of the air is 71%. The average wind speed is 2.8 m/s. Winter is characterized by stable frosty weather, thaws are rare. Precipitation falls, as a rule, in the form of snow. Extreme temperatures of the winter months, both minimum and maximum, as well as maximum monthly average temperatures, are close to each other. Spring comes in the third decade of March-early April. The average daily temperature passes the mark of 0°C, on average, on April 6, the mark of 5 ° C — on April 20, and the mark of 10 ° C — on May 7.

2.6. Primary vegetation (before the creation of the agrocenosis)

It is mainly caused by the typical vegetation of the steppe, such as *Stipa pennata*, *Festuca valesiaca, Koeleria pyryata*, *Poa pratensis*, *Helictotrichon sempervirens*. Vegetation is represented by such species as *Galatella biflora*, *Heracleum sibiricum, Pleurospermum uralense, Iris ruthenica, Thalictrum minus*.

2.7. Cultivated crops

Cereals (spring wheat, oats and others), as well as a number of vegetable crops (various types of cabbage, tomatoes, eggplants, zucchini, squash, pumpkin and others), various types of greens, berry crops (strawberries) are grown on the territory of the enterprise.

2.8. Agricultural machinery used

Each of the crops is grown using certain agricultural techniques, but the method is based on minimizing the use of mineral fertilizers, as well as the use of a number of soil-saving technologies. The main fertilizer is compost based on cow manure. A four-field crop rotation is used. The farm tries to minimize the use of mechanical tillage, due to its rapid drying and the risk of weathering. In order to save the soil, namely the retention of soil aggregates, the farm uses the technology of mulching and the use of agrofibre. Basically, this method is used in the agrotechnics of strawberries and tomatoes grown in the open ground. When growing cabbage, this technology is not used. When growing potatoes, this technology is used only for the previous crop. The positive aspect of using mulch and agrofibre is that there is a moisture conservation and a soil-retaining effect; also important is the property of mulch to prevent the growth of weeds, which makes it possible to abandon the use of herbicides. The negative point here may be that in the humid environment created by mulch, there is a rapid spread of pathogens, so it is important to observe the humidity in the surface layer of the soil and plant diversity, as one of the methods to prevent the spread of pathogens.

The farm, due to the possibility of growing many crops in the open ground, uses standard mechanized equipment with a tendency to minimize its use. For this reason, until recently, irrigation was carried out on the farm using a sprinkler machine, but with the start of the program to minimize mechanical impact on the soil, the owners switched to the use of drip irrigation - and it is used both in the open ground and in greenhouses.

The main and practically the only fertilizer used on the farm is compost, prepared from manure. In addition to the plant-growing direction, there is an organic technology livestock farm at the enterprise. In this regard, large volumes of organic cow manure are available, from which, according to a certain technology, compost is prepared and applied to the fields in a crushed state. In addition to compost, ash is added to the soil in small quantities as a mineral additive.

3. Research Results

3.1. Examination of soil samples for humus content

Humus has a sedimentation effect on the soil. And in the absence, or with a low content of clay minerals, the organic component, including the product of its transformation humus, has a strengthening effect on the soil. The results of quantitative determination of humus are presented in Table 1. Standard statistical calculations are carried out (Table 2).

Since the P-value between the groups is less than 1, Fischer's criterion can be considered significant. Consequently, the humus content in soil samples depends on the use of organic fertilizer. We compare the values of F experimental and F tabular: 7.081>3.0087. Thus, it is statistically reliably established that the factor of organic fertilizer application affects the humus content in the soil.

Figure 2 shows a diagram showing the quantitative content of humus in the soil in fields where organic fertilizers were applied and in fields where they were not applied.

Based on the data obtained on the humus content in the samples under study, it can be said that its content increased in plots with the use of organic fertilizers (experimental

Table 1. Results of quantitative analysis of humus content in experimental and control soil samples.

Factor A	Factor B	Repetition				Amounts, V	Average values, *x*
		I	II	III	IV		
Control samples	Field 1	5.9	6.2	6.1	6.1	24.3	6.11
	Field 2	5.7	5.9	5.4	5.5	22.5	5.63
	Field 3	6.0	6.5	6.3	6.1	24.9	6.23
	Field 4	6.3	6.7	6.4	6.4	25.8	6.45
Prototypes	Field 5	8.1	8.9	7.6	8.6	33.2	8.31
	Field 6	8.3	8.7	7.8	8.9	33.7	8.43
	Field 7	7.9	7.8	7.4	7.1	30.2	7.55
	Field 8	8.6	8.9	8.8	8.9	35.2	8.82

Table 2. Statistical processing of the results of quantitative determination of humus in control and experimental soil samples.

Source of variation	SS	df	MS	F	P-meaning	F- meaning
Selection	37.845	1	37.845	350.687	$7.93 \cdot 10^{-16}$	4.2596
Columns	2.461	3	0.820	7.602	0.0009	3.0087
Interactions	2.292	3	0.764	7.081	0.0014	3.0087
Inside	2.590	24	0.108			
Total	45.188	31				

SS = the sum of squares; df = degrees of freedom; MS = middle square; F = Fisher test.

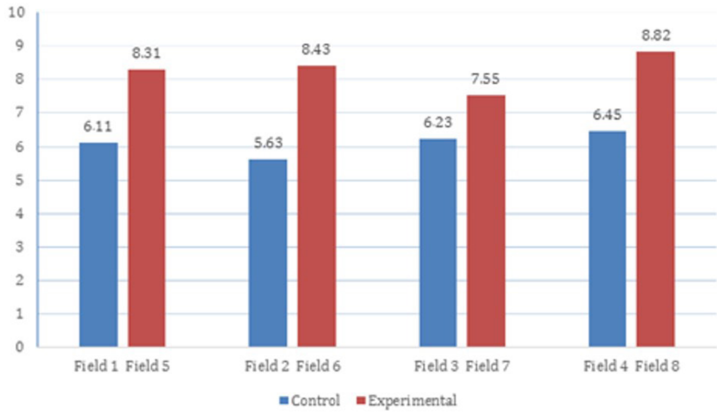

Figure 2. Humus content in fields cultivated by organic technology and in fields where this technology has not been used.

Table 3. Results of quantitative analysis of the content of mobile forms of phosphorus in experimental and control soil samples.

Factor A	Factor B	Repetition				Amounts, V	Average values, x
		I	II	III	IV		
Control samples	Field 1	11.9	11.2	10.3	10.7	44.1	11.0
	Field 2	12.1	11.9	12.3	12.5	48.8	12.2
	Field 3	9.9	10.5	9.2	10.9	40.5	10.1
	Field 4	13.2	12.5	14.0	14.1	53.8	13.4
Prototypes	Field 5	20.1	19.8	22.2	21.9	84.0	21.0
	Field 6	25.4	23.3	24.6	24.9	98.2	24.5
	Field 7	28.9	27.6	27.7	28.6	112.8	28.2
	Field 8	24.4	26.5	24.9	23.1	98.9	24.7

fields 5, 6, 7, 8), in relation to experimental points located in their immediate vicinity, in the same fields (control fields with numbers 1, 2, 3, 4 without the use of organic fertilizer). The humus content in ordinary chernozem is about 5.5-6.0%, which confirms the assumption of maintaining the level of humus content on soils of long-term use, under conditions of application of organic fertilizers and other agrotechnical techniques characteristic of organic farming.

3.1.1. Investigation of soil samples for the content of mobile forms of phosphorus

The question of the content of mobile forms of phosphorus is important when assessing soil fertility. As you know, the plant can directly assimilate only the mobile form of phosphorus. There are also gross phosphorus, which is completely inaccessible to plants and is a long- term reserve. Many plants, such as legumes, secrete metabolites into the soil to mobilize the gross forms of phosphorus. At the same time, rhizospheric bacteria actively contribute to this, which is a high prospect for abandoning the use of phosphorus fertilizers and using only the soil component.

The problem with the use of phosphorus fertilizers can be called the fact that phosphorus, being in anionic form, is strongly bound to soil aggregates and is not capable of movement by an exchange mechanism or by capillary current. This causes the fact that phosphorus after application remains at the depth to which it was introduced and does not migrate along the soil profile. On the other hand, this is one of the reasons why phosphorus fertilizers are applied directly with planting material.

The results of quantitative determination of mobile forms of phosphorus are presented in Table 3.

Table 4 shows the statistical processing of the results obtained.

Since the P-value between the groups is less than 1, Fischer's criterion can be considered significant. We compare the values of F experimental and F tabular: 32.12 > 3.01. Consequently, the phosphorus content in soil samples statistically significantly depends on the application of organic farming technology.

Figure 3 shows a diagram showing the quantitative content of mobile forms of phosphorus in the soil in the fields of organic farming, and in fields where organic farming has not been used.

Thus, the conducted research shows that the phosphorus content in the soil correlates with the introduction of organic material and the total content of mobile forms of phosphorus increases.

Table 4. Statistical processing of the results of quantitative determination of mobile forms of phosphorus in control and experimental soil samples.

Source of variation	SS	df	MS	F	P- meaning	F- meaning
Selection	1335.15	1	1335.15	1680.97	$9.8\cdot10^{-24}$	4.26
Columns	52.18	3	17.39	21.90	$4.7\cdot10^{-7}$	3.01
Interactions	76.56	3	25.5	32.12	$1.43\cdot10^{-8}$	3.01
Inside	19.06	24	0.79			
Total	1482.96	31				

SS = the sum of squares; df = degrees of freedom; MS = middle square; F = Fisher test.

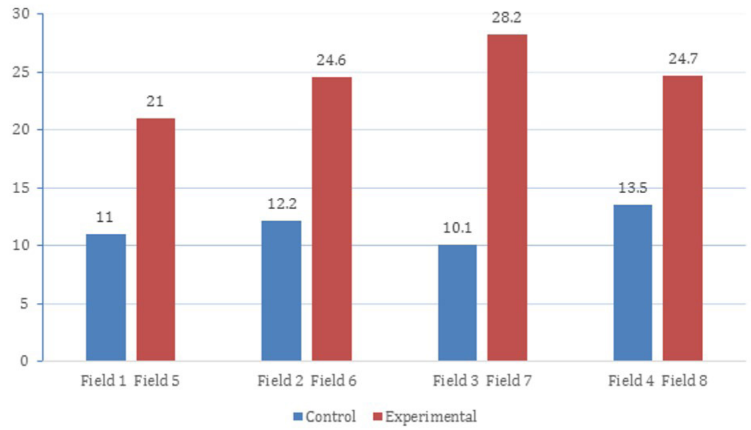

Figure 3. The content of mobile forms of phosphorus in fields cultivated by organic technology and in fields where this technology has not been used.

3.1.2. Investigation of soil samples for the content of mobile forms of potassium

Information about the content of mobile forms of potassium is important in the agrochemical analysis of soils. Potassium in the soil in different states (exchangeable, non-exchangeable, water-soluble, potassium in the composition of anhydrous silicates, potassium in the plasma of microorganisms) can be available to the cultivated crop only in one state - exchangeable. And moving to the place of absorption through the soil capillaries, potassium should remain in the exchange form. It is for this reason that there is a high need for potash fertilizers, including on chernozems. Potash fertilizers are used both in the main and in the seed application. And of course, this does not mean that organic fertilizers do not contain its mobile forms. Yes, they are much less than in mineral fertilizers, but this is not the main parameter of the influence of organic fertilizers on the state of potassium in the soil. First of all, this is an improvement in the physico-chemical characteristics, including an increase in the mobile forms of potassium due to the action of both microorganisms and the absorbing effect of the organic component (potassium migration). The results of quantitative determination of mobile forms of potassium are presented in Table 5. Table 6 shows the statistical processing of the results obtained.

Since the P-Value between the groups is less than 1, Fischer's criterion can be considered significant. We compare the values of F experimental and F tabular: 3.7784 > 3.0087. Consequently, it has been statistically reliably established that the factor of organic fertilizer application, as well as other agrotechnical techniques of organic farming technology contribute to an increase in the potassium content in the soil.

Figure 4 shows a diagram showing the quantitative content of mobile forms of potassium in the soil in the fields of organic farming, and in fields where organic farming has not been used.

Based on the data we obtained during this analysis, we confirmed that the studies conducted earlier in this area have similar results and prove the validity of the previously proposed hypothesis. As the works for which the comparison was conducted, such as Fan et al. (2023), Butkevičienė et al. (2023).

4. Conclusion

Application of organic farming technology, including agrotechnical techniques, for 8 years on ordinary chernozems of Western Siberia: composting based on cow manure; ash application; mulching; crop rotation; minimal tillage; minimizing the use of chemical fertilizers

Table 5. Results of quantitative analysis of the content of mobile forms of potassium in experimental and control soil samples.

Factor A	Factor B	Repetition				Amounts, V	Average values, *x*
		I	II	III	IV		
Control samples	Field 1	11.5	11.4	12.2	9.2	44.3	11.1
	Field 2	12.7	12.9	11.5	11.3	48.4	12.1
	Field 3	10.1	9.8	9.2	10.8	39.9	9.9
	Field 4	11.2	10.9	9.9	10.4	42.4	10.6
Prototypes	Field 5	14.1	13.5	14.4	13.9	55.9	13.9
	Field 6	14.5	13.1	13.4	13.4	54.4	13.6
	Field 7	14.6	14.2	13.2	13.1	55.1	13.7
	Field 8	12.3	14.3	15.4	14.1	56.1	14.0

Table 6. Statistical processing of the results of quantitative determination of mobile forms of potassium in control and experimental soil samples.

Source of variation	SS	df	MS	F	P-meaning	F- meaning
Selection	67.5703	1	67.5703	92.4697	$1.05 \cdot 10^{-9}$	4.2597
Columns	4.0084	3	1.3361	1.8285	0.1689	3.0087
Interactions	6.0909	3	2.0303	3.7784	0.0629	3.0087
Inside	17.5375	24	0.7307			
Total	95.2071	31				

SS = the sum of squares; df = degrees of freedom; MS = middle square; F = Fisher test.

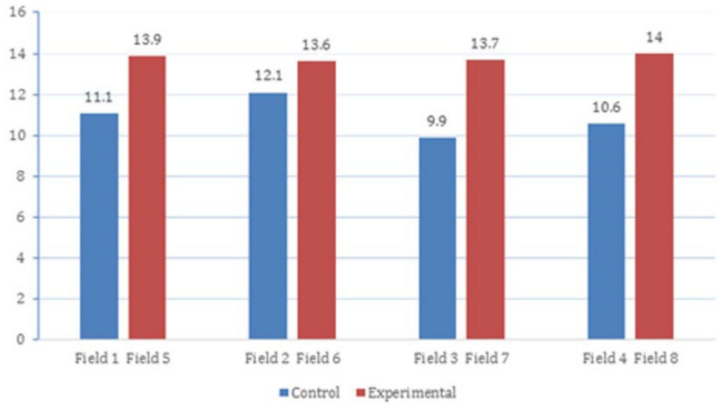

Figure 4. The content of mobile forms of potassium in fields cultivated by organic technology and in fields where this technology was not used.

and plant protection products, has a positive effect on the condition of soils. The conducted studies show a statistically significant increase in the content of the most important components of the soil: humus, mobile forms of phosphorus, mobile forms of potassium. The positive effect of organic fertilizer on the content of humus, as one of the soil structure-forming agents, has been established. Organic fertilizers contribute to an increase in the content of mobile forms of phosphorus and potassium in the arable horizon. Perhaps, in large agro-industrial enterprises, the introduction of organic matter should not imply a complete replacement of mineral fertilizers with it. Rather, organic fertilizers act as a compensatory measure to the often destructive and negative effects of chemical fertilizers. But the experience of the described farm shows the beneficial effect of organic farming on restoring soil health and enriching them with nutrients.

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