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The state of soil fertility during long-term use of fertilizers in agrocenosis

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Abstract. The long-term stationary experiment (1981-2011) on meadow-Chernozem soil has shown that the systematic application of mineral fertilizers and straw, the inclusion of perennial legumes in the crop rotation stabilizes the humus content and increases the supply of labile organic matter in the soil. The humus content in the fertilized variants increased by 0.16-0.30 %, and the content of easily mineralized organic matter by 24-86%. High correlation dependence (r=81) of humus content on mortmass reserves in soil confirms the significant role of labile organic matter in soil fertility preservation.

1. Introduction
The role of soil organic matter in the complex of factors determining their effective fertility and, consequently, the productivity of crops is leading [1]. Soil organic matter is one of the main sources of mineral nutrition for plants. However, the real contribution to the formation of available nutrients is made by its easily mineralized (labile) components [2].

According to studies, the content of labile organic matter (LOM) is a sensitive indicator of changes in soil fertility and depends on agricultural technologies used in crop rotation, fertilizer systems, the duration of agrochemical agents' usage and a set of crops in crop rotation [3-6]. The amount of LOM determines effective fertility level, which is easily subjected to biodegradation of microbial flora of the soil, providing plants with basic nutrients. Pool of LOM in the agro-ecosystem according to I. N. Sharkova [3] primarily depends on the quantity and quality of incoming crop residues. The use of fertilizers in crop rotation is of paramount importance. In this regard, the purpose of the research was to assess the state of soil fertility during long-term use of fertilizers.

2. The conditions of the experiment

2.1. Soil conditions
The studies were carried out in 2009-2011 in a long-term stationary field experiment, founded in 1988 at the experimental site of the Omsk Agrochemistry laboratory in the southern forest-steppe zone of Western Siberia. The soil cover of arable lands of the southern forest-steppe is represented mainly by ordinary, leached chernozems and meadow-Chernozem soils of medium and heavy granulometric composition.

The soil of the experimental site is meadow-chernozem, medium-powerful, medium-humus, heavy-loamy. 0-20 cm. layer initially contains: 6.4–6.6% of humus (Tyurin), mobile phosphorus and

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potassium exchange – respectively 105-128, and 350-420 mg/kg of soil (Chirikov). The amount of exchange cations was 32.1 mg-EQ/100 g of soil. The share of Ca2+ – 89, MD2+ – 11, sodium less than 1%, phkcl 6.4–6.7. in of cations

2.2 The research methodology.

Many years' experience is based on six-grain grass crop rotation. Alternation of crops in rotation: 3-year-old lucerne–wheat–wheat–oats. Crop rotation is deployed in time and space. The research was carried out before sowing of the wheat in the lucerne.

The following factors were being studied:

Factor A – application of mineral fertilizers: 1) without fertilizers; 2) the application of dose N10P17; 3) the application of dose N15P23. The fertilizer system in crop rotation is presented in table 2. Factor B – the use of straw: 1) without straw; 2) the introduction of straw after harvesting crops in an amount corresponding to the harvest.

The experience is based on the method of split plots, the area of elementary plots – 200 m^2 (10×20), databased – 36 m^2 (1.8×20). The repetition of the experience is fourfold.

Table 1. Scheme of fertilizer application in grain-grass crop rotation.

N	Fertilizer system		Lucerne	Wheat	Wheat	Oats
1	Without fertilizers	without straw	-	-	-	-
2		straw	-	-	-	-
3-4	$N_{10}P_{17}$	without straw	P_{60}	-	$N_{30}P_{40}$	N_{30}
		straw	P_{60}	-	$N_{30}P_{40}$	N_{30}
5	$N_{15}P_{23}$	without straw	P_{60}	-	$N_{60}P_{40}$	$N_{30}P_{40}$
6		straw	P_{60}	-	$N_{60}P_{40}$	$N_{30}P_{40}$

Ammonium nitrate with active substance N-34% and ammophos – N-12% and P-52% was used as a mineral fertilizer. Fertilizers were applied in the spring before planting locally by drill to a depth of 6-8 cm. Cereal straw was shredded at harvest and left in the field in the amount corresponding to its crop.

The main tillage in the crop rotation – dump autumn plowing to a depth of 20-22cm. Moisture is closed in the spring by tooth harrows in two tracks to create a mulching layer of soil in 2-3 cm, followed by rolling ring rollers. Before sowing - presowing cultivation with application of mineral fertilizers (ammonium nitrate, ammophos). Sowing was carried out in the optimal time for the crops types zones selected by Siberian Agricultural Scientific Institute. Spring soft wheat variety in memory of Aziyev, oats hulless Siberian oats, flora 5 lucerne.

Before sowing wheat, 4 mixed samples from the 0-25 cm layer were selected on each plot in two noncontiguous repetitions to determine the following parameters: total carbon – by Tyurin in the modification of Nikitin [7], carbon of mortmass – by Tyurin in the modification of Yanishevsky [8]. The definition of gross nitrogen (soil layer of 0-20 cm) and nitrate nitrogen (layer of 0-40 cm) with disulphophenyl acid (Grandval-Lyage) was made according to Kjeldahl – Modellbauer The gross nitrogen content in the mortmass was determined from one sample by the Pinevich method.

The research results were processed by dispersion and correlation methods of statistical analysis [9].

3. Results

The study of soil samples showed that the initial humus content in the six-field grain-grass crop rotation, where 50% of the arable land are occupied by perennial legumes (lucerne) without the use of fertilizers was at level of 6.73%. For three rotations of the grain-grass crop rotation it has not changed: 6.72% (-0.01) (table 2).

The organic matter balance in the soil was provided by Lucerne cultivation in the rotation (50% of the area). Studies in a number of Russian regions have shown that the inclusion of perennial legumes in the crop rotation allows to preserve soil fertility due to their ability to fix atmospheric nitrogen of the air and accumulate a large number of root and stubble residues. During their mineralization macro - and microelements, biologically active substances are released [10].

Table 2. The content and reserves of humus in the soil, depending on the use of fertilizers and straw.

Option	Humus %	Deviation +/-, %	
		From control	From source
Without fertilizers	6.72	-	-0.01
Straw	6.71	-0.01	-0.04
$N_{10}P_{17}$	6.88	0.16	0.20
$N_{10}P_{17}$ + straw	6.88	0.16	0.15
$N_{15}P_{23}$	7.02	0.30	0.25
$N_{15}P_{23}$ + straw	7.02	0.30	0.24
$HCP_{05\ mineral\ fertilizers}$		0.09	0.07
HCP_{05} straw		Fф<Fт	Fф<Fт
HCP_{05} private average		0.13	0.10

The systematic use of mineral fertilizers in crop rotation increased the humus content in the soil by 0.16 – 0.30%. The formation of humus on mineral backgrounds happens due to the large flow of organic material in the form of plant and root crop residues.

The use of straw in its pure form and against the background of mineral fertilizers did not provide significant changes in the accumulation of humus in comparison with the options without straw.

The annual flow of plant residues into the soil forms a fund of easily mineralized compounds, including in the form of mortmass (fresh and semi-decayed plant and animal residues).

Optimization of mineral nutrition in crop rotation due to the use of mineral fertilizers and straw increased soil enrichment with mortmass carbon by 24 – 86%. The increase was determined by the type and dose of fertilizer (table 3).

Systematic use of straw in doses of 1.68-2.20 t/h provided only a tendency to increase the carbon of mortmass in the soil, due to the low yield of straw. Mineral fertilizers were a significant factor affecting the carbon content of mortmass in the soil. The carbon content of mortmass in the soil (on agrochemical backgrounds N10P17 and N15P23) was 960 and 1095 mg/kg; 41 and 61 % higher than the variant without fertilizers. The largest amount of carbon of mortmass has accumulated in the variant of complex application of fertilizers (N15P23 + straw) -1262 mg/kg, which is 86% higher than on an inconvenient background.

It should be noted that as a part of the total carbon, the proportion of mortmass carbon was 1.74%. When applying mineral fertilizers, it increased to 2.40 – 2.68%, which indicates a positive impact on the increase of the carbon mortmass content in the organic matter of the soil.

Table 3. The carbon mortmass content ($C_{mort.}$) depending on the application of mineral fertilizers and straw, mg/kg.

Option	$C_{mort.}$	Growth		%, from $C_{general}$
		Mg/kg	%	
Without fertilizers	679	-	-	1.74
Straw	841	162	24	2.15
$N_{10}P_{17}$	960	281	41	2.40
$N_{10}P_{17}$ + straw	1152	473	70	2.88
$N_{15}P_{23}$	1095	416	61	2.68
$N_{15}P_{23}$ +straw	1262	583	86	3.09
HCP_{05} mineral fertilizers – 316; HCP_{05}straw - Fф<Fт; HCP_{05} private average - 446				

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The labile part of soil organic matter determines not only the level of effective fertility, but also influences the quantitative value of the conservative (stable) part of humus [2]. The correlation analysis showed a close relationship between the humus content in the soil and the soil enrichment with mortmass (figure 1).

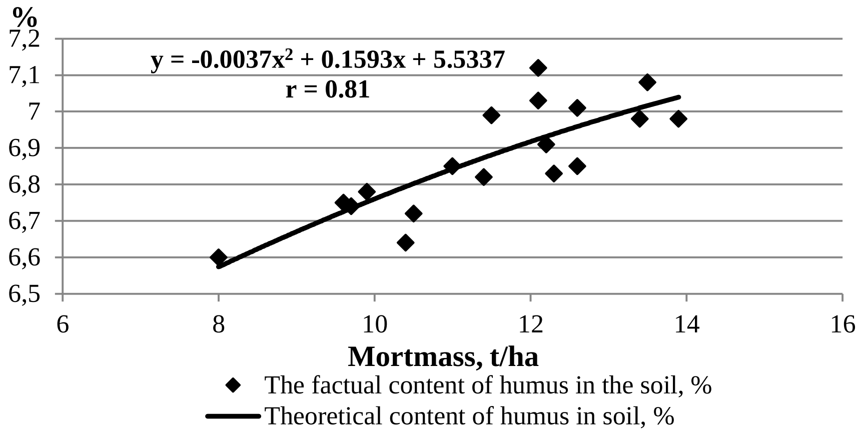

Figure 1. The dependence of the humus content in the soil (Y, %) of the resources of the mortmass (X, t/ha).

The soil nitrogen is the main source of nitrogen nutrition of plants in the agricultural communities of Siberia. Tjhnthe main part of soil nitrogen (82-89%) is a part of humus. The near reserve for mineralization is made up of organic substances that are part of the easily viralized labile fraction (stubble, root, post-harvest plants, biomass and waste products of soil fauna and flora, etc.). Long-term use of fertilizers has a stabilizing effect on the nitrogen fund of soils – the content of total and easily mobile organic nitrogen compounds, as well as the number of mobile mineral forms increases [1].

Studies have found that the total nitrogen content in the soil was in the range from 0.29 to 0.31%, without significant changes depending on the studied factors (table 4).

Table 4. Stocks of total nitrogen ($N_{tot.}$) and nitrogen mortmass ($N_{mortm.}$) depending on application of mineral fertilizers and straw.

Option	$N_{tot.}$ kg/h	$N_{mortm.}$ kg/h	Growth kg/h	Growth %	%, from $N_{tot.}$
Without fertilizers	6.38	143.8	-	-	23
Straw	6.60	162.2	18.4	13	25
$N_{10}P_{17}$	6.82	188.1	44.3	31	28
$N_{10}P_{17}$ + straw	6.82	203.8	60.0	42	30
$N_{15}P_{23}$	6.82	198.4	54.6	38	29
$N_{15}P_{23}$ + straw	6.82	233.6	89.8	62	34
HCP_{05} mineral fertilizers	$F_ф < F_т$	12.9			
HCP_{05} straw	$F_ф < F_т$	15.8			
HCP_{05} private average	$F_ф < F_т$	22.4			

The content of gross nitrogen in the mortmass varied from 1.58 to 1.73%, without significant regularities from the studied factors. The differentiation of variants by the reserves of mortmass nitrogen was determined by the amount of mortmass in the soil. It was found that due to the systematic application of fertilizers in the crop rotation, the nitrogen reserves of the mortmass increased by 31% and 38%, compared with the option without fertilizers. The use of straw provided a positive trend of increasing nitrogen reserves in the mortmass. The largest amount was observed in the organomineral fertilizer system ($N_{15}P_{23}$ + straw), respectively, 233.6 kg/h

As a part of the total nitrogen of the soil, the proportion of nitrogen of the mortmass was 23%. When applying mineral fertilizers, it increased to –23 - 34%, which indicates a positive effect on the mortmass nitrogen content increase in the organic matter of the soil.

Due to the fact that a significant part of the most accessible nitrogen to plants comes from labile organic matter, a correlation analysis of the dependence of the nitrate nitrogen content in the soil on the reserves of nitrogen of the mortmass has been made. The results confirm a close relationship among these indicators (figure 2).

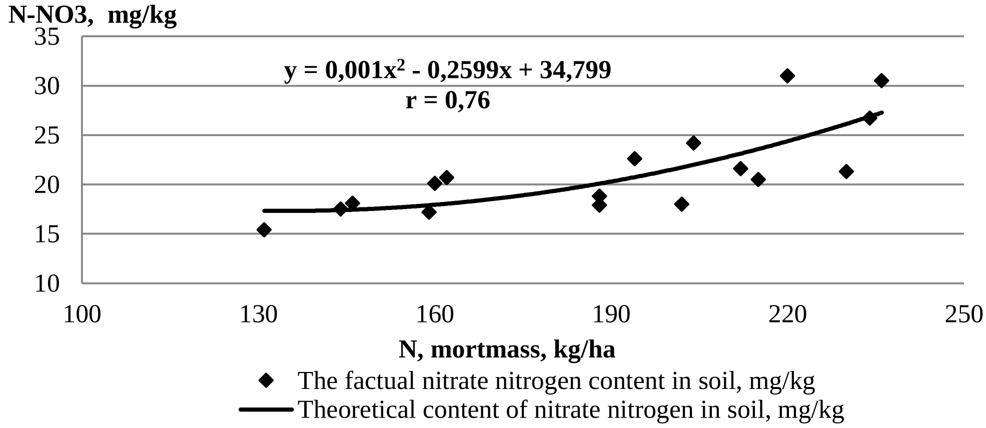

Figure 2. Dependence of nitrate nitrogen content in the soil (layer 0-40 cm) (Y mg/kg) from the resources of mortmass nitrogen (X kg/ha).

4.Conclusion

Thus, the studies show that the systematic use of mineral fertilizers at dose of $N_{15}P_{23}$ and straw in the grain-grass crop rotation contributes to an increase in the reserves of labile organic matter in the soil, which ultimately ensures the preservation of soil fertility and the additional flow of easily mineralized organic nitrogen.

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