Changes in humus content in sod-podzolic soils as a result of agricultural use

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Abstract. The purpose of the research is to study the effect of long-term application of fertilizers on the dynamics of humus in the sod-podzolic medium-loam soil of the Republic of Mari El. It was found that in the control grain-grass crop rotation on the natural soil fertility for 24 years, the humus content in the soil gradually decreased. By the end of the second rotation, it decreased by 0.03 %, in the third-by another 0.08 % and the fourth-by 0.02 %. The content of humus in the soil of the first fruit-bearing crop rotation decreased even more intensively than in the control. By the end of the first rotation, the content of humus in the natural soil fertility decreased by 0.05 % compared to the initial state. In 2007, at the end of the second rotation, humus in the first crop rotation decreased by 0.09...0.10 % from the initial state. In 2013 - by 0.16...0.17 %. The lowest humus content -1.55 % for all the time of research was in the soil of the first fruit-bearing crop rotation at the end of the Quad rotation against the background of natural soil fertility. The difference compared to the initial state in this variant was -0.17 %. The highest humus content was in the soil of the second crop rotation, where rotted manure was applied under potatoes-80 t / ha. By the end of the first rotation, the humus content in the soil of the crop rotation increased by 0.03...0.04 %. The difference compared to the initial state in this variant was -0.11 % relative to the first rotation, the third-by 0.10...0.12 %, the fourth-by 0.20...0.21 %. Against a background without fertilizers, the humus content was always higher than when using N60P60K60. The most stable humus content was in the soil of the third crop rotation. In this rotation of six fields, two fields were under perennial legumes. During three rotations, the content of humus in the soil in this crop rotation was within the range of 1.72...1.74 %. Only after the fourth rotation, the humus content decreased to 1.70...1.73 %.

1. Introduction
Soil fertility mainly depends on the amount, composition of humus and basic soil nutrients (NPK). On lands that are in agricultural circulation, due to the reduction of biomass reserves in the soil, a shortage of humus is gradually formed. The optimal humus content in sod-podzolic soils, which ensures a high planned yield of all crop rotation crops and meets the biological requirements of cultivated plants, is at the level of 2.5 % with a reserve of 75 t / ha. The main criterion for assessing the state of soil fertility is the content of humus and mobile forms of nutrients. Humus is a part of the soil that performs one of the main functions in creating the necessary conditions for the growth and development of plants. It contains plant nutrition elements that are formed in the soil during mineralization [1, 2].
Lowering the potential soil fertility leads to many negative consequences: the quality of humus and agrophysical properties of soils deteriorate, and the yield is inevitably reduced. The problem of increasing crop productivity while simultaneously preserving and reproducing soil fertility is currently the most acute [3, 4].

Each crop has its own optimal level of humus content in the soil, which ensures its maximum productivity. Currently, there is a huge amount of data in the literature that suggests that one of the main factors determining the potential fertility of the soil is the content of humus in it. It is no accident that there is a close relationship between soil humus and crop productivity. In the range of humus content of sod-podzolic soil from 1.35% to 3.08%, an increase in humus content by 0.5 % is accompanied by an increase in the yield of barley grain by 5-6 C/ha.

The organic matter content in the soil should not decrease, but rather increase, i.e., fertility should improve. All this can be achieved by observing crop rotation and conducting complex agrochemical cultivation [5].

In the studies of A. K. Ulanova, L. V. Budazhapov and A. S. Biltueva, it was shown that the increase in humus content was in the variant with the introduction of 40 t / ha of manure into the steam field. Application of manure provided a positive balance of humus, the excess of the initial content was 30.5 %, or 11 t / ha of humus. This was facilitated by a total increase in the organic matter content not only due to the introduction of manure, but also a greater intake of root and crop residues relative to the control [6]. The decrease in the content of organic matter in the same experiment led to a decrease in the total nitrogen of the soil, quantitative changes in its fractional composition. One of the main methods of regulating soil fertility is the use of organic and mineral fertilizers in crop rotation [7].

Soil humus, formed from organic substances and compounds of plant, animal and microbial origin that have passed the humification and non-humification stages of stabilization, forms and supports the main functions of the soil and gives it a unique property – the creation and preservation of soil fertility [8, p.17].

In 2007-2015, the research conducted in the Ural research Institute of agricultural research on dark gray soil studied the effectiveness of biologization techniques on the balance of humus in two rotations of field crop rotations. With a small amount of manure and compost, a negative balance of humus was formed in the range of 0.4 to 0.43 t / ha. The average annual intake of dry crop-root residues into the soil within 3.4-5.2 t / ha provided compensation for the humus deficit by 60-95 %. The greatest balance of humus was achieved in grain-grass crop rotations, the minimum - in grain-grass crop rotation. The presence of two clover fields in the crop rotation makes it possible to fully compensate for the loss of humus from its mineralization [9].

Scientists of the Belarusian state agricultural Academy found that when the humus content in the soil is less than 2.00 %, the highest grain yield (from 4.65 to 7.15 t / ha) barley, provides a dose of nitrogen fertilizer 140 kg d. V./ha (80 kg / ha in the main filling and 60 kg / ha-in the top dressing in the end-tillering phase-the beginning of the exit to the tube). When the humus content in the soil is from 2.00 to 2.50%, the doses of nitrogen fertilizer N80+60 and N80+40 provide an equal grain yield (from 6.98 to 5.15 and from 6.93 to 5.00 t / ha, respectively). When cultivating barley on plots with a humus content of 2.50 % [10].

The purpose of the research is to study the effect of long-term application of fertilizers on the dynamics of humus in the sod-podzolic medium-loam soil of the Republic of Mari El.

The use of mineral fertilizers is closely related to the main task of agricultural production - to increase crop productivity and quality while preserving soil fertility and ecological balance. If they are used for a long time, it is important to prevent soil degradation. The need to use mineral fertilizers in the agroecosystem is caused by a changed cycle of nutrients due to the constant alienation of a significant part of the nutrition elements from the soil by crop yields.

2. Material and methods

Stationary experience in studying the effectiveness of fertilizers in field crop rotations deployed in time was established in 1996 at the experimental field of the Mari research Institute of agricultural research.
The soil of the experimental site is sod-podzolic medium loam, had the following agrochemical indicators before planting crop rotations: humus content - 1.72%, Phsol - 5.67, Hg - 1.41 mg EQ per 100 g of soil, the sum of absorbed bases - 8.9 mg EQ per 100 g of soil, P2O5 - 270 and K2O – 130 mg per 1 kg of soil (according to Kirsanov). Agricultural equipment of crops is generally accepted for the Republic of Mari El. The repetition of variants in the experiment is threefold, the arrangement of plots in them is systematic. The total area of plots of the first order is 330 m², the second-165 m². The accounting area is 165 m².

Experience scheme

Factor A - types of crop rotations
1. grain-Grass – (oats + clover, clover 1. g. p., winter crops, vetch/oats for grain, spring wheat, barley) – 83% of grain-control.
2. I fruit-bearing – (vetch/oats for green mass, winter crops, barley, potatoes, vetch/oats for grain, spring wheat) – 67% of cereals.
3. II fruit-bearing – (vetch/oats for grain, spring wheat, potatoes (manure 80T / ha), barley + clover, clover 1 g. p., winter) - 67 % of cereals.
4. III fruit-bearing – (barley + clover, clover 1 g. p., clover 2 g. p., winter crops, potatoes, oats) - 50% of grain.

Factor B-mineral fertilizers:
1. Control (without fertilizers)
2. N60P60K60.

In the second crop rotation, bedding manure was applied to potatoes 80 t / ha. Mineral fertilizers were applied in a balanced ratio of the main elements according to N60P60K60 in the form of ammonium nitrate, double superphosphate and potassium chloride. Nitrogen fertilizers were not applied to perennial legumes and their predecessors.

3. Results and its discussion

In 2019, the fourth rotation of crop rotations ended. This allowed us to analyze the dynamics of humus in the soil for 24 years of research. Studies have shown that in the control grain-grass crop rotation on the natural soil fertility there is a gradual decrease in the content of humus (table 1). So in 2007, after the first rotation in comparison with the original content, it decreased by 0.03 %, in 2013, after the second rotation by another 0.08 %, in 2019, after the third rotation by 0.02 %. Against the background of mineral fertilizers in this crop rotation, there was also a decrease in the content of humus in the soil, when more intense, when less.

The content of humus in the soil of the first fruit-bearing crop rotation decreased even more intensively than in the control. So in 2001, the natural soil fertility humus content fell in comparison with the initial state by 0.03 %, and against the background of mineral fertilizers, the humus content decreased even more and amounted to 1.67 %. This is 0.05% lower than the original state. In 2007, at the end of the second rotation of crop rotations, the soil humus in the first crop rotation decreased by 0.09...0.10 % compared to the initial state. Over 18 years of research, the humus content decreased in this crop rotation by another 0.16...0.17 %. The lowest humus content for the entire research period of 1.55 % was in the soil of the first crop rotation in 2019 against the background of natural soil fertility. The difference compared to the initial state in this variant was -0.17 %.

Table 1. Influence of crop rotation types and use of mineral fertilizers on the dynamics of humus content in the arable soil layer.

| Crop rotation   | Fertilizers       | Humus content, % |
|-----------------|------------------|-----------------|
|                 |                  | 2001 y. | 2007 y. | 2013 y. | 2019 y. |
| Grain and grass | Without fertilizers | 1.70     | 1.67    | 1.59    | 1.57    |
|                 | NPK              | 1.70     | 1.64    | 1.60    | 1.56    |
| I fruit bearing | Without fertilizers | 1.69     | 1.63    | 1.56    | 1.55    |
|                 | NPK              | 1.67     | 1.62    | 1.55    | 1.58    |
The highest content of humus was in the soil of the second crop rotation, where rotted manure was applied to potatoes 80 t/ha. In 2001, the humus content in the soil of this crop rotation increased by 0.03...0.04%, in 2007-by 0.11%, in 2013-0.10...0.12%, in 2019-0.20...0.21%. Moreover, it is characteristic that the humus content was always higher against a background without fertilizers than when using N60P60K60.

The most stable humus content was in the soil of the third crop rotation. In this rotation of six fields, two fields were under perennial legumes. During three rotations of crop rotation, the humus content in the soil was within the range of 1.72...1.74%. Only after the fourth rotation of crop rotations, the humus content decreased to 1.70...1.73%.

As for the mathematical processing of research, in 2001, the increase in humus content was within the error of experience, both for factor A and factor B. In 2007 and 2013, the increase was reliable only for crop rotations, for mineral fertilizers they were within the error of experience. In 2019, the increase in humus content significantly exceeded both factor A (crop rotation) and factor B (mineral fertilizers).

4. Conclusion

Thus, the results of long-term stationary studies allow us to conclude that the negative balance of humus in the soil was formed in the control (grain-grass) and I fruit-bearing crop rotations. Moreover, the decrease in humus within the error of the experiment relative to the third fruit-bearing crop rotation was in the grain-grass crop rotation only in the first rotation. In subsequent rotations, the decrease in humus content was mathematically provable. Non-deficit balance of humus in the soil, in our experiments revealed in crop rotation III crop rotation, and positive in the II crop rotation.

References

[1] Dergacheva M And 2010 Reflection of bio -, geo - and anthropospheric interactions in soils and soil cover Mat. Conf – - the Doctrine of soil humus: a look into the past and present (Tomsk) pp 63-7
[2] Kozlova L M Noskova E N and Popov F A 2019 Agrarian science of the Euro-North-East 20(5) 467-77
[3] Zhuchenko A A 2015 Bulletin of agroindustrial complex Stavropol 2 9-13
[4] Zamyatin S A Efimova A Ju 2016 Development and implementation of soil-protecting energy-saving technologies - the main way to improve the profitability and environmental safety of crop production at the present stage: materials vsros. scientific.-pract conf with int participation, 7-8 July 2016, FEDERAL state scientific institution research Institute of agriculture Udmurtskaya Izhevsk Izhevsk state agricultural Academy 60-5
[5] Romanova A S Merkulov N V and Grevtsev E Yu 2014 Questions of steppe studies
[6] Ulanov A K Budazhapov L V and Biltuev A s 2017 Agrochemistry 9 90-6
[7] Biltuev A S Ulanov A K 2018 Soil fertility and agricultural productivity assessment Proceedings of the scientific and production conf with international participation pp 169-77
[8] Semenov V M Kogut B M 2015 Soil organic matter (Moscow GEOS) p 233
[9] Zezin N N Postnikov P A and Namyatov M A 2019 Perm agrarian Bulletin 2(26) 57-64
[10] Vorobyov V B Grishchenko I Yu and Lastochkina S I 2018 Bulletin of the Belarusian state agricultural Academy 2 98-101