Comparative evaluation of the biological activity of the arable layer of sod-podzolic soil in the Non-chernozem zone (Smolensk region) depending on the fertilizer system

D A Postnikov¹,³, G E Merzlaya², A D Fedulova¹, K V Postnikova²

¹ Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, Moscow, Russia
² Pryanishnikov Institute of Agrochemistry, Moscow, Russia
³ E-mail: dimpost1962@gmail.com

Abstract. Long field experiments were carried out using two methods for assessing biological activity in the arable layer of sod-podzolic soil. The biological activity of the soil was established by the intensity of decomposition of the linen and using tea bags at the junction of the methodology of the University of Utrecht (Netherlands) and Umeå (Sweden). It was noted that the biological activity of the soil with a rating of "strong" was on all options, but only when using mineral components as fertilizer. In 2017, in the option using only phosphorus fertilizer, the biological activity was rated "very strong". In variants using the organomineral system, the biological activity of the soil was rated “strong” and “very strong”. When determining the biological activity of the soil by the method of decomposition of organic matter of tea, similar results were obtained. As a consequence, against the background of organic and organomineral systems, it was proved that the biological activity of sod-podzolic soil in the conditions of the western part of the Non-chernozem zone is maximum.

1. Introduction

The main goal is to analyze the long-term aftereffect of organic and mineral fertilizers in different doses and combinations of environmental indicators of sod-podzolic light loamy soil.

In studies, it is noted that the biological activity of the soil in terms of the rate of decomposition of cellulose is an important agronomic and environmental characteristic [1,2]. According to the experiments conducted by A. Artemyev on drained sod-podzolic soils, the degree of decomposition of cellulose depends on the methods and depth of tillage [3]. It was also noted that on sod-podzolic soil, the decomposition of flax tissue in the soil depends on the depth of cultivation and culture, it was noted that under lupine the decomposition rate is higher, and under wheat this indicator is lower [4]. On a long field experiment at the Timiryazev Academy, it was noted that microbiological processes are more active under potatoes and this affects the rate of cellulose decomposition [5]. Some authors note that the application of mineral fertilizers [6,7] increases the rate of decomposition of flax tissue in the soil. However, we did not reveal such a feature in the conditions of the Smolensk region when using various doses of mineral components. It was noted that in the lower part of the arable layer, the rate of tissue
decomposition is always lower [8], and the more intense decomposition of linen on the lower part of the slope [9].

2. Material and methods of research
Studios were conducted in 2015-2018, on the experience laid in the village of Olsha, Smolensk region in 1978, from 1978 to 2008. 4 rotations took place, in which the effect of various fertilizer systems was studied. In the 5th and 6th rotation of crop rotation, the aftereffect of fertilizer systems was studied.

The experimental design is an abbreviated factorial one, represented by a sample of 1/27 (6x6x6x6). In the experiment, four factors were studied in six doses: manure, nitrogen, phosphorus, potassium fertilizers - 0, 1, 2, 3, 4, 5.

The laying and conducting of the experiment was carried out in accordance with the Program and research methodology in the geographical network of experiments on the integrated use of chemicals in agriculture.

Five rotations of crop rotation took place during the experiment (Table 1).

| 1 rotation (1979–1989) | 2 rotation (1990–1995) | 3 rotation (1996–2000) | 4 rotation (2002–2008) | 5 rotation (2009–2015) |
|------------------------|------------------------|------------------------|------------------------|------------------------|
| potatoes               | potatoes               | potatoes               | annual herbs (oats for green food) | annual herbs (oats for green food) |
| barley                 | barley                 | perennial grasses 1 year of use | winter rye              | winter rye              |
| winter rye             | perennial grasses 1 year of use | perennial grasses 2 year of use | barley                  | barley                  |
| winter rye             | perennial grasses 2 year of use | perennial grasses 2 year of use | perennial grasses 1 year of use | perennial grasses 1 year of use |
| oats                   | winter wheat           | oats                   | spring wheat - oats      | spring wheat - oats     |
| pea-oat mix            | winter wheat           | oats                   |                         |                        |
| winter rye             | barley                 |                         |                         |                        |
| barley                 | perennial grasses 1 year of use |                         |                         |                        |
| winter rye             | perennial grasses 2 year of use |                         |                         |                        |
| winter rye             |                        |                        |                         |                        |

The saturation of crop rotation by crops from the first to fifth rotation was 54, 50, 50, 57, 57% (average - 54%); perennial herbs - 18, 33, 33, 28, 28% (average - 28%).

In the first three rotations, cattle manure with a small amount of litter was used as organic fertilizer, and compost based on manure and peat was used in the fourth rotation.

In the first rotation of the crop rotation, organic fertilizers were applied for potatoes and winter wheat; in the second and third rotations - for potatoes; in the fourth rotation - under winter rye. Fertilizers contained 0.46% total nitrogen on raw material, 0.08% ammonium nitrogen, 0.21% P2O5, 0.66% K2O. The organic matter content on dry weight is 59%, the ratio C: N is 19. The gross content of heavy metals in the fertilizer is Cd - 0.1, Cr - 1, Ni - 1, Cu - 0.6, Zn - 7 mg kg-1 dry mass.

The unit calculated dose of organic fertilizer is 3.2 tons (rounded 3 tons). Together with 1 ton of organic fertilizer, 580 kg of organic matter, 14.5 kg of nitrogen, 6.6 kg of phosphorus, 20.7 kg of potassium were applied to the soil per 1 ha per year. With one calculated dose of organic fertilizer (manure or compost) for 30 years of experience, 17.4 tons of organic matter, 435 kg of total nitrogen, 198 kg of phosphorus (P2O5), 621 kg of potassium (K2O) were released into the soil.
The following mineral fertilizers were introduced into the soil: ammonium nitrate, double superphosphate, potassium chloride. A single dose of nitrogen, phosphorus and potassium corresponded to 25.5 kg of active ingredient per 1 hectare. For 4 rotations of crop rotation with mineral fertilizers, 765 kg ha\(^{-1}\) of nitrogen, phosphorus and potassium were delivered to the soil.

In the experiment, triplicate. The total area of the plot is 112 m\(^2\) (7x16 m), 48 m\(^2\) (4x12 m) - accounting.

The paper presents the studies conducted in the fifth rotation of the grain-grass crop rotation in two fields where Skakun oats were grown, with the support of the introduction of ammonium nitrate in a dose of N45 in the background in all variants of the field experiment.

The soil of the experimental plot was cultivated sod-podzolic light loamy, pH 5.5-6.4, humus content 1.3%, mobile phosphorus (P\(_2\)O\(_5\)) and potassium (K\(_2\)O) (according to Kirsanov) 160 and 120 mg kg\(^{-1}\), respectively.

Before laying the experiment and after each field season, an agrochemical analysis of the soil was carried out according to the traditional method (0-20 cm).

The biological activity of the soil was determined:
- by the rate of web decomposition by the method of E. N. Mishustin, I. S. Vostrov and A. N. Petrova [10];
- by the method of decomposition of organic matter using tea bags according to the joint methodology of the University of Utrecht (Netherlands) and the University of Umea (Sweden) under the International Program with the participation of the Geographic Network of Experiments with Fertilizers VNIIA [11].

Used linen and bags of green tea. For two years, the rate of decomposition of the material in the experimental plots was taken into account.

3. Results and discussion
In 2017-2018, studies were conducted to determine the biological activity of the soil in the experiment by various methods. The research results are presented in tables 2 and 3.

**Table 2. Cellulose-degrading ability of microbial communities in soil.**

| Experience Option | Decomposition of flaxseed linen, % | 2017 r. | Degree of decomposition | Decomposition of flaxseed linen, % | 2018 r. | Degree of decomposition |
|-------------------|-----------------------------------|---------|------------------------|-----------------------------------|---------|------------------------|
| 1. Control        | 59                                | Strong  | 93                     | Very strong                       |
| 2. N90            | 61                                | Strong  | 90                     | Very strong                       |
| 3. P90            | 80                                | Very strong | 79                  | Strong                            |
| 4. K90            | 79                                | Strong  | 78                     | Strong                            |
| 5. 9 t ha\(^{-1}\) dung | 59                            | Strong  | 85                     | Very strong                       |
| 6. N90P90K90      | 77                                | Strong  | 73                     | Strong                            |
| 7. N30P30K30 +    | 81                                | Very strong | Very strong | Very strong                       |
| 3t ha\(^{-1}\) dung |                                  |         |                        |                                   |
| 8. N60P60K60 +    | 51                                | Strong  | 87                     | Very strong                       |
| 6 t ha\(^{-1}\) dung |                                  |         |                        |                                   |
| 9. N90P90K90 +    | 76                                | Strong  | 83                     | Very strong                       |
| 9 t ha\(^{-1}\) dung |                                  |         |                        |                                   |
| 10. N120P120K120  | 86                                | Very strong | 96                  | Very strong                       |
| 12 t ha\(^{-1}\) dung |                                  |         |                        |                                   |
| 11. N150P150K150  | 53                                | Strong  | 92                     | Very strong                       |

In 2017, according to the experimental options, it was noted that the mineral system when using only nitrogen fertilizer does not significantly affect the rate of decomposition of linen in the soil.
In our opinion, this is due to the inhibition of soil biota, which actively destroys cellulose. Phosphorus fertilizer increases the decomposition of linen, which from an environmental point of view is the expected result and is favorable in general for the agricultural sector. It should be noted that in 2018, against the background of nitrogen fertilizer, we already noted a positive dynamics in the rate of decomposition of linen fabric. Probably, this year meteorological conditions contributed to increased activity of soil biota, and this indicator approached the same in the control variant - 90 and 93%, respectively. But the most interesting from an agroecological point of view, the results were obtained using the organomineral system in version 10. A four-fold dose, according to the mineral and organic components, is most optimal under the prevailing conditions on sod-podzolic soil. It should be emphasized that the five-fold dose in the 11th variant in 17 year is significantly inferior to the indicator from the control variant and only in the 18th year the biological activity of this variant practically does not differ from the control, but less than in the 10th variant - 92 and 93% respectively.

When using tea bags, the following results were obtained: in 2018, on the control variant with green tea, the decomposition percentage is 56.7, and with a five-fold dose of fertilizers 53.4%. The maximum decomposition of the organic matter of green tea was achieved in the variant with the mineral fertilizer system (N90P90K90) - 65.2%. When using rooibos tea bags, the decomposition percentage of organic tea was 51.8.

| Bookmark location | % Decomposition, 2017 | % Decomposition, 2018 |
|-------------------|-----------------------|-----------------------|
|                   | green | rooibos | green | rooibos |
| Forest            | 58,1  | 56,4    | 56,7  | 38,9    |
| Meadow            | 67,2  | 24,3    | 56,6  | 42,6    |
|                   | Control | 58,4 | 32,0 | 57,6 | 35,3 |
|                   | 9 t ha\(^{-1}\) of manure | 58,5 | 26,4 | 58,1 | 47,7 |
|                   | Field experience | N90P90K90 | 64,1 | 26,1 | 65,2 | 50,8 |
|                   | N90P90K90 + 9 t ha\(^{-1}\) of manure | - | - | 62,8 | 43,8 |
|                   | N150P150K150 + 15 t ha\(^{-1}\) of manure | - | - | 53,4 | 51,8 |

Lipton tea bags of two types - green and rooibos were laid together with linen in different experiment variants, as well as in natural ecosystems - in a forest belt and in a meadow. It should be noted that the percentage of decomposition of green tea is much higher than that of rooibos tea. Rather, all this is due to the qualitative composition of the organic matter of tea varieties.

As you know in the agricultural sector, we strive to get the most out of the use of all factors of intensification of agricultural production. The fertilizer system, as one of the components of the intensification system, is undoubtedly decisive at this stage in the development of agricultural production. Compared to crops even 30 years ago, we began to get more grain, milk and potatoes per unit area. But in the enthusiasm for the technogenic approach in agricultural production, one should not forget about biological processes in the soil censos, which has a certain potential for effective fertility. Our task is to use this potential, supporting it in terms of compliance with the principles of organic farming.

4. Conclusion

The biological activity of the soil depends on the level of fertilizer application in the after-action. With the aftereffect of moderate two and three-fold doses in organomineral systems, this indicator was 51-67%. According to the results of taking into account the biological activity of the soil, the doses of N90P90K90 + 9 t ha\(^{-1}\) and N120P120K120 + 12 t ha\(^{-1}\) manure, respectively, should be considered an environmentally sound dose of applying the fertilizer system.
When using tea bags according to the data for 2018, the maximum percentage of decomposition of the organic matter of rooibos tea was achieved using the maximum dose of organic fertilizers.

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