

Changes in the biological activity of typical chernozem under different pea cultivation technologies

*Elena Dubovik**, *Dmitry Dubovik*¹, *Aleksander Morozov*¹, *Aleksander Shumakov*¹, and *Tatyana Novikova*²

¹Federal Agricultural Kursk Research Center, building 70b, Karl Marx street, Kursk, 305021, Russia

²Southwest State University, 94, 50 Let Oktyabrya street, Kursk, 305040, Russia

Abstract. The preservation of soil fertility is a critical task in modern agriculture, necessitating the adoption of technologies that conserve soil resources. This study aimed to investigate the biological activity of typical chernozem under various pea cultivation technologies. The research was conducted on the experimental field of the Kursk Federal Agrarian Research Center, utilizing traditional, differentiated, minimal, and direct sowing methods. The soil used was typical thick heavy loamy chernozem. The study employed the gravimetric method to measure humidity, the application method for the decomposition of flax to assess biological activity, and the Kravkov method to determine the nitrification capacity of the soil. The results showed that differentiated, minimal, and direct sowing technologies for pea cultivation significantly enhanced the nitrifying ability and biological activity of the soil, with average increases of 1.2-1.8 times compared to traditional technology in the 0-20 cm soil layer. These findings highlight the potential benefits of adopting alternative pea cultivation technologies to promote soil conservation and fertility preservation.

1 Introduction

Soil fertility is formed because of the soil-forming process and is determined by the totality of its properties. One of these properties is its biological activity, which reflects the level, nature and ecological state of soil fertility [1]. In turn, the intensity and direction of the biochemical activity of microbiological processes is determined by the rational use of agricultural land. At the same time, the activity of microbiological processes with a favorable combination of temperature, humidity and density of the soil is also determined by the content of organic matter in it [2]. The positive effect of the presence of organic matter on the activity of soil microflora, and on the activity of cellulose-degrading microorganisms, is also noted when adding manure [3]. Lack of precipitation and excess temperature conditions contribute to a decrease in the activity of cellulose-decomposing microorganisms [4].

Changes in both the composition and functioning of microbial communities inhabiting not only the soil, but also the rhizosphere can be noted during various agricultural soil

* Corresponding author: dubovikev@yandex.ru

treatments [5, 6]. Thus, in the soil and climatic conditions of the Central Black Sea region, a favorable course of microbiological processes was noted when growing barley at a depth of 14-16 cm to 20-22 cm, regardless of the method of treatment, but the use of surface and zero tillage leads to a decrease in biological activity [7]. When studying cellulolytic activity on ordinary chernozems of the Bashkir Trans-Urals using no-till technology, a weak and very weak intensity of cellulose decomposition is noted, and the highest is noted with traditional processing technology in the upper layer of 0-10 cm [8]. At the same time, in the conditions of the Stavropol Territory, high biological activity was revealed in variants using zero and minimum tillage, and when using moldboard plowing, this indicator was much lower [9].

The purpose of these studies was to study various pea cultivation technologies on the biological activity of typical chernozem.

2 Materials and methods

The research was carried out on the experimental field of the Kursk Federal Agrarian Research Center in 2020-2023. The experiment was launched in 2015 in a four-field grain crop rotation, deployed in space by all four fields, with the following alternation of crops: peas - winter wheat - soybeans - spring barley.

The following pea cultivation technologies have been studied in the experiment:

1. Traditional technology consists of the use of moldboard tillage (plowing at 20-22 cm), the main application of $N_{15}P_{40}K_{40}$ kg/ha and fertilizing in the budding phase of N_{34} kg/ha in dry conditions. Integrated plant protection system combining mechanical treatments and chemicals.

2. Differentiated technology consists of a combination of shallow (disking at 8-10 cm) and moldless (chiselling at 20-22 cm) tillage, the main application of $N_{15}P_{40}K_{40}$ kg/ha and fertilizing in the budding phase N_{34} kg/ha in a.i. Integrated plant protection system combining mechanical treatments and chemicals.

3. The minimum technology consists of the use of surface treatment (discing up to 8 cm), the main application of $N_{15}P_{40}K_{40}$ kg/ha and fertilizing in the budding phase of N_{34} kg/ha in a.i. Integrated plant protection system combining mechanical treatments and chemicals.

4. Direct sowing technology - consists of sowing a crop without mechanical tillage (No-till technology), the main application of $N_{15}P_{40}K_{40}$ kg/ha, with sowing $N_{10}P_{26}K_{26}$ kg/ha and fertilizing in the budding phase N_{34} kg/ha in dry conditions. A chemical plant protection system, including the use of continuous action herbicides in the fall after harvesting the predecessor, and in the spring before sowing peas.

The options in the field experiment are systematically placed in one tier. The area of the sowing plot is 6000 m² (60 × 100), repeated three times. Pea variety was Jaguar. Sowing was carried out using SZ-5.4 and Don 114 seeders.

The soil of the experimental plot is represented by typical thick heavy loamy chernozem. The average humus content in the arable layer is 5.40-5.51%, mobile phosphorus and exchangeable potassium (according to Chirikov) are 15.7-19.3 and 10.8-11.7 mg/100 soil, respectively. The reaction of the soil environment is slightly acidic (pH 5.3-5.6).

The study of humidity was carried out by the gravimetric method. The determination of the biological activity of typical chernozem was studied using the application method based on the decomposition of flax, which was laid down during the pregenerative period of plant development in the second stage of organogenesis; the exposure period was 30-35 days [10]. The degree of intensity of fiber destruction was assessed using the D.G. Zvyagintsev's scale based on the following gradation: <10% - very weak, 10-30% - weak, 30-50% - medium, 50-80% - strong, >80% - very strong. The determination of the nitrification capacity of the soil was carried out using the Kravkov method (version of the V.V. Dokuchaev Soil Institute). The following scale was used for assessing nitrification capacity (mg NO₃/kg): <5.0 – very

low; 5.1-8.0 low; 8.1-15.0 average; 15.1-30.0 – increased; 30.1-60.0 – high; >60.0 – very high. The work presents average data for the second rotation of crop rotation. Statistical data processing was carried out using Microsoft Excel and Statistica programs. The correlation dependence was assessed using the Chaddock scale, which includes the following gradation: 0.1-0.3 – weak; 0.3-0.5 – moderate; 0.5-0.7 – noticeable; 0.7-0.9 – high; 0.9-0.99 – very high.

3 Results and discussion

The development of microbiological processes in the soil is determined by nitrification capacity and biological activity. The intensity of these processes is determined primarily by soil moisture.

As a result of the research, a change in the moisture content of chernozem typical for various pea cultivation technologies was established (Fig. 1).

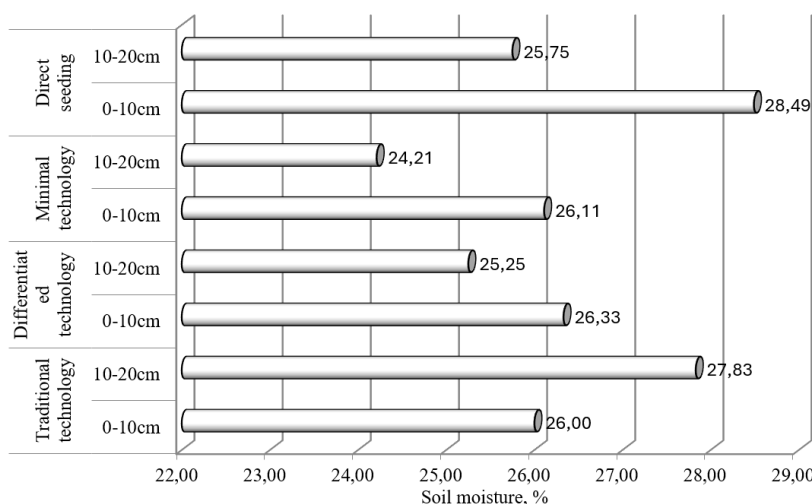


Fig. 1. Humidity of chernozem typical for various pea cultivation technologies.

It was revealed that in the 0-10 cm layer, soil moisture when using direct sowing technology is 7.6-8.7% higher compared to traditional, differentiated and minimal technologies. In the layer of 0-10 cm compared to the layer of 10-20 cm, there is an increase in humidity with energy-efficient agricultural technologies (differentiated, minimal and direct sowing) by 7.7-9.6% compared to traditional technology. With traditional technology, the moisture content in the soil in the 10-20 cm layer was 7% higher than in the top layer.

Nitrification is the most important microbiological process that completes the transformation of nitrogen-containing organic compounds in the soil. The influence of pea cultivation technologies on nitrifying ability is presented in Fig. 2. It was established that the nitrifying ability of typical chernozem, regardless of the layer studied, in the variant with traditional technology was 1.1-1.6 times lower compared to the use of differentiated, minimal and direct sowing technology. At the same time, the nitrifying ability of the soil in the 10-20 cm layer was higher than in the upper layer of 0-10 cm in options using energy-efficient agricultural technologies (differentiated, minimal and direct sowing). In the variant using traditional technology, changes in the nitrifying ability of typical chernozem in the studied layers were insignificant - ~5%. In general, it can be noted that the nitrification capacity of the soil, regardless of the technology used for pea cultivation and the layer studied, was increased (16.8-26.7 mg NO₃/kg).

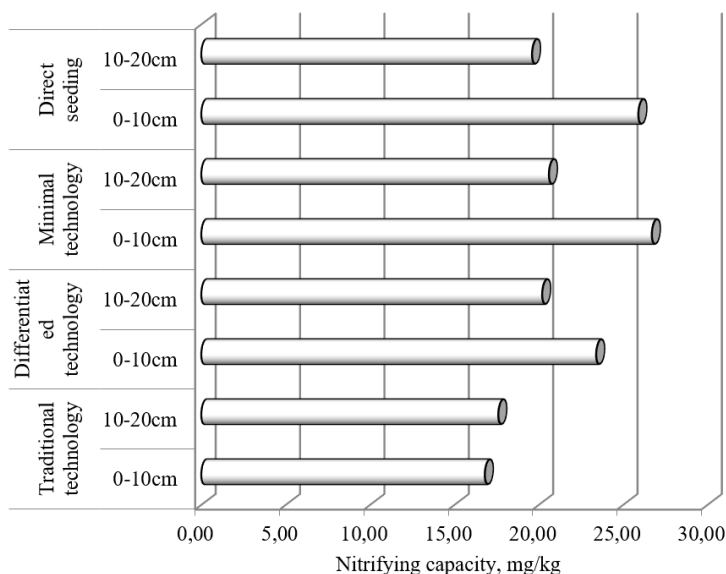


Fig. 2. Nitrifying ability of chernozem typical for various pea cultivation technologies.

Figure 3 shows the change in the biological activity of typical chernozem under different pea cultivation technologies. Thus, in a layer of 0-10 cm using traditional technology, biological activity was minimal 10.45% and, depending on the minimization of technology, increased in the series: differentiated (16.36%) → minimal (23.37%) → direct sowing (24.19%).

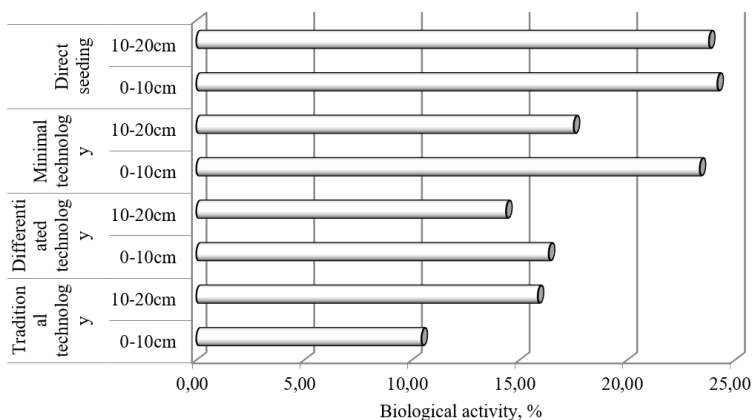


Fig. 3. The biological activity of chernozem typical for various technologies of pea cultivation.

In the 10-20 cm layer, biological activity when using direct sowing technology was 1.4-1.7 times higher in relation to the technologies being studied. At the same time, for differentiated and minimal technologies there is a decrease in biological activity with the depth of the studied layer by 12 and 25%, respectively. With direct sowing, the change in this indicator across layers was insignificant - ~2%. In the variant with traditional technology, the biological activity of the soil increased with increasing layer depth, and in the 10-20 cm

layer it was 1.5 times higher than in the 0-10 cm layer. At the same time, regardless of the pea cultivation technology and the depth of the studied layer, the biological activity was assessed as weak, since the destruction of fiber ranged from 10 to 30%.

Analysis of the correlation coefficients between biological activity and humidity, as well as between biological activity and nitrification ability showed a noticeable ($r=0.56$) and high ($r=0.79$) relationship in the 0-10 cm layer. In the 10-20 cm layer the correlation coefficient between the studied indicators showed their weak relationship ($r=0.10$). At the same time, the correlation between nitrification capacity and humidity was direct and moderate in the 0-10 cm layer ($r = 0.33$) and very high and inverse in the 10-20 cm layer ($r = -0.99$).

4 Conclusion

Thus, it was found that soil moisture under direct seeding technology was higher than under other technologies studied. The nitrification capacity of the soil, regardless of the pea cultivation technology used and the layer studied, was increased (16.8-26.7 mg NO₃/kg), and biological activity was weak (10-30%). At the same time, when using the following pea cultivation technologies - differentiated, minimal and direct sowing, on average in a layer of 0-20 cm, the nitrifying ability of the soil and biological activity were 1.2-1.8 times higher compared to options with traditional technology. High nitrification capacity and biological activity of the soil indicate both good cultivation of the soil and the active occurrence of nitrification processes and nitrogen loss, which is due, on the one hand, to an increase in soil moisture, and on the other, to the physiological characteristics of the crop under study.

References

1. N. Fierer, S.A. Wood, C.P.B. de Mesquita, *Soil Biol. Biochem.* **153** 108111 (2021) doi: 10.1016/j.soilbio.2020.108111
2. A.N. Kuzminykh, S.I. Novoselov, G.I. Pashkova, *IOP Conf. Series: Earth and Environmental Science* **421** 022017 (2020) doi: 10.1088/1755-1315/421/2/022017.
3. E.C. Coonan, C.A. Kirkby, J.A. Kirkegaard, M.R. Amidy, C.L. Strong, A.E. Richardson, *Nutrient Cycling in Agroecosystems* **117** 273–298 (2020). doi: 10.1007/s10705-020-10076-8.
4. J. Jabiol, F. Colas, F. Guérol, *Water Res.* **170** 115295 (2020).doi: 10.1016/j.watres.2019.115295.
5. M.A. Komissarov, A. Klik, *Eurasian Soil Science* **53(4)** 503-511 (2020). doi: 10.1134/S1064229320040079.
6. J. Sasse, E. Martinoia, T. Northen, *Trends Plant Sci.* **23(1)** 25-41 (2018). doi: 10.1016/j.tplants.2017.09.003.
7. V.M. Garmashov, I.M. Kornilov, N.A. Nuzhnaya, V.N. Govorov, M.P. Kryachkova, L.V. Garmashova, *Bulletin of Michurinsky State Agrarian University* **3(58)**, 22-27 (2019).
8. G.R. Ilbulova, Ya.T. Suyundukov, I.N. Semenova, R.F. Khasanova, M.B. Suyundukova, Kh.M. Safin, *Achievements of science and technology of the agro-industrial complex* **36(4)** 66-71 (2022). doi: 10.53859/02352451_2022_36_4_66.
9. G.V. Mokrikov, K.Sh. Kazeev, M.A. Myasnikova, Yu.V. Akimenko, S.I. Kolesnikov, *Agrochemical Bulletin* **5** 31-36 (2019). doi: 10.24411/0235-2516-2019-10071.
10. G.I. Bazdyrev, I.P. Vasilyev, A.M. Tulikov, A.V. Zakharchenko, A.F. Safonov, *Agriculture* (M.: NIC INFRA-M, 2018)