# Effectiveness of Cover Crops on No-Till in the Middle Volga Forest-Steppe

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Abstract: Using the example of rapeseed cultivation for seeds, it is proved that using No-till technology, cover crops improved the conditions for growth and development of the next crop in the crop rotation. When sowing a mixture of spring Cover crops after harvesting the previous barley, the yield of the next rapeseed in the crop rotation increased from 0.09 t/ha or 8.7% (without fertilizers) to 0.19 t/ha or 10.1% (against the background of N80P30K46S5). The combined use of mineral fertilizers and Cover crops increased the use of fertilizers by plants for crop formation, which, in our opinion, is explained by the increased microbiological activity of the soil and their wider biological diversity. When sowing winter cover crops, there were no differences in productivity compared to the control variants of the next spring rapeseed, which is explained by the high consumption of moisture by cover crops from the soil, the more the situation worsened in the conditions of drought, which manifested itself in the spring-summer period of 2023.

## 1 INTRODUCTION

Priority directions of agriculture development on a global scale are associated with the search for effective low-cost environmentally acceptable agricultural technologies that serve as a guarantee of stable development of agricultural production, while it is important to reduce the cost of production and the negative impact of intensification means on the environment (Liebert, Mirsky, Pelzer, Ryan, ,2023; Tiefenbacher, Sandén, Haslmayr, Miloczki, Wenzel, Spiegel, 2021).

In recent years, minimal tillage systems and direct seeding technologies have become increasingly widespread (Ferreira, 2020), including in Russia (Dridiger, Stukalov, Gadzhiumarov, 2019). The modern strategy of the direct seeding system provides for a gradual transition to soil-protective and energy-saving agriculture, which is based on the development of biologization techniques (Toigildin, Morozov, Podsevalov, Ayupov, 2020). This technology meets certain requirements, it minimizes interference with the soil, while ensuring the constant presence of plants and their living roots in the soil, fertility is preserved, the costs of fuel and lubricants, depreciation and repair of equipment are reduced, and this is not a simplification of existing systems, but a complex technology, with the correct application of which the main problems of agriculture are minimized (Mokrikov, Kazeev, Akimenko, 2017; Hess, Hinckley, Robertson, Hamilton, Matson, 2018).

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The advantage of direct seeding technology lies in several aspects, first of all, it will allow the accumulation of plant residues of previous crops on the surface, which provides the soil with wind resistance, reducing unproductive evaporation of moisture; protect plants from infestation; reduce losses of organic matter and others (Dridiger, Belobrov, Stukalov, 2019). The effectiveness of the system is evaluated in different ways, so, according to a number of scientists and practitioners, the development of this system allows to increase crop yields in about 15% of cases, in 5% there is a decrease and in 80% of cases the yield does not change in comparison with traditional methods of land use (Blanco-Canqui, Wortmann, 2020).

The methodology of studying the technology of direct seeding in Russia is at the stage of formation. The advantage of this technology was appreciated only by individual enterprises that successfully continue to learn and implement it. Given the territorial fragmentation, the diversity of soil and climatic conditions, scientists will have to conduct a lot of research and develop practical recommendations for the development of this technology.

Chernozem soils have favorable biological, agrophysical and agrochemical properties for plants. Currently, many researchers point to the degradation of soil fertility, while the reasons are intensive tillage, violation of the regime of organic matter, insufficient application of mineral fertilizers, erosion processes, etc. (He, Chaolan, Qun, 2020).

The technology of direct seeding allows solving a number of these problems, but it is also not without drawbacks (Jemison, Welcomer, Kersbergen, Majewski, 2018; Çelik, Günal, Acar, M. 2019; Zavalin, Belobrov, Yudin, Dridiger, 2018) It is believed that when cultivating crops without tillage, the problem of the impact of the undercarriages of harvesting machines and equipment on the soil arises, which leads to the destruction of its structure and over-compaction, which requires a detailed study of this issue.

The purpose of the research: to study the effect of mineral fertilizers and cover crops on the yield of spring rapeseed and product quality indicators on No-till technologies in the conditions of the forest-steppe zone of the Middle Volga region.

# 2 MATERIALS AND RESEARCH METHODS

Evaluation of the effectiveness of the use of cover crops was carried out in the stationary field experience of the Department of Agriculture, Crop Production and Breeding of the Ulyanovsk State Agrarian University, which implies the study of the following crop rotation: spring rapeseed - winter wheat - soy - spring wheat - buckwheat - barley.

Factors studied: mineral fertilizer rates (factor A) and cover crops (Factor B).

Factor A – fertilizer rate:

$A_0$ – without fertilizers (corresponds to the level of extensive agricultural technologies);

$A_1$ – supporting fertilizer rates (corresponds to the level of normal agricultural technologies);

$A_2$ – recommended fertilizer rates for the region (corresponds to the level of intensive agricultural technologies) (Table 1).

Table 1: Scheme of experience in studying the effect of mineral fertilizer rates on rapeseed productivity in direct sowing.

| Variant | Type of fertilizer and the content of the active substance | Norm, kg/ha | Dose, in active substance kg/ha | Method of fertilization |
|---|---|---|---|---|
| 1 | No fertilizers | 0 | 0 | - |
| 2 | Complex fertilizer NPK(S)8:19:29(3)+0,2Zn | 80 | $N_6P_{15}K_{23}S_2$ | During sowing |
| | Ammonium nitrate (34) | 100 | $N_{34}$ | Top dressing in the phase of 3-4 leaves |
| 3 | Complex fertilizer NPK(S)8:19:29(3)+0,2Zn | 160 | $N_{13}P_{30}K_{46}S_5$ | During sowing |
| | Ammonium nitrate (34) | 100 | $N_{34}$ | Top dressing in the phase of 3-4 leaves |
| | Ammonium nitrate (34) | 100 | $N^{34}$ | Top dressing in the stalking - budding phase |

Factor B – cover crops:

$B_0$– without cover crops;

$B_1$ – sowing of spring cover crops after harvesting grain crops (the composition of the mixture: daikon, radish, vetch, lentils, oats, Sudan grass, phacelia, flax, the seeding rate of the mixture is

13.5 kg/ha).

$B_2$ – sowing of winter cover crops after harvesting grain crops (composition of the mixture: winter rye, winter vetch, the seeding rate of the mixture is 25 kg/ha).Protection of crops from harmful organisms consisted in seed etching (Insure Perform, SC 0.4 l/t), vegetation treatment with herbicide (Prima Donna, SE 0.5 l/ha), insecticide (Fastac, EC 0.1 l/ha), fungicide (Rex Plus, SE 0.8 l/ha).

Table 2: Composition of mixtures and seeding rates of cover crops in the field experiment.

| Mixture of spring crops ($B_1$) | | Mixture of winter crops ($B_2$) | |
|---|---|---|---|
| Cultures of a mixture cover-ground crops | Estimated seeding rate, kg/ha | Cultures of a mixture of cover-ground crops | Estimated seeding rate, kg/ha |
| Spring vetch | 3.13 | Winter rye | 12.5 |
| Lentil | 3.13 | Winter vetch | 12.5 |
| Oats | 4.69 | - | - |
| Sorghum-Sudanese hybrid | 0.25 | - | - |
| Radish | 0.47 | - | - |
| Daikon | 0.31 | - | - |
| Flax | 1.25 | - | - |
| Phacelia | 0.31 | - | - |
| **Total** | **13.5** | - | **25.0** |

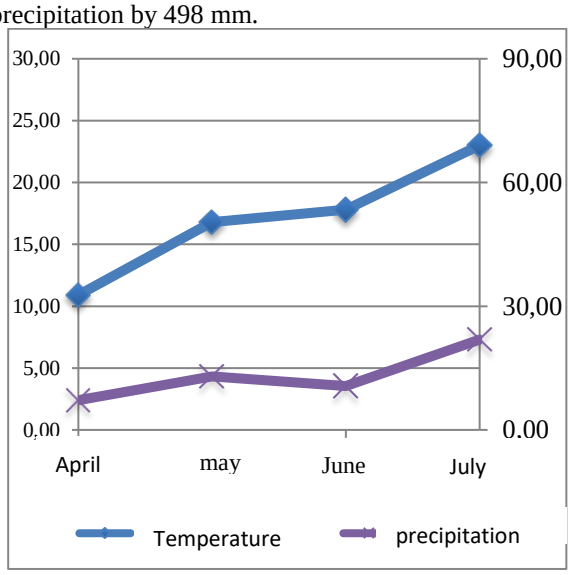
The repetition of the experience is 3-fold, the placement is systematic by the method of overlay. The size of the plots of the first order is 648 $m^2$ (36*18), the second is 216 $m^2$ (12*18).

The soil of the experimental site is medium-loamy leached chernozem with the following characteristics - according to the humus content, the soil of the experimental site is low-humus, the reaction of the medium in the arable soil layer is slightly acidic, the content of mobile phosphorus and exchangeable potassium is high.

In 2023 (the year of the research), the amount of precipitation for May-July was 45.5 mm, with an average daily air temperature in May - 11.6 ˚C, in June - 17.6 ˚C and in July - 21.9 ˚C, and the hydrothermal coefficient = 0.26 units.

For a more complete description of weather conditions, we used climagrams constructed using the method of H. Walter, which allow us to better assess weather conditions and the degree of dryness of conditions during the growing season, which is achieved by selecting a scale on the graph, according to which the average daily air temperature in degrees Celsius and the average monthly precipitation in millimeters are indicated for each month (for every 10 degrees of air there is 30 mm of precipitation). If the temperature line is higher than the precipitation line, a dry period develops, and if the precipitation line is higher than the temperature line, then the period is characterized as humidified and more favorable for plant growth and development.

The analysis showed that dry conditions developed in 2023 – the total evaporation for the period April-July prevailed over the amount of precipitation by 498 mm.




Figrку 1: Climagram for 2023, hydrothermal coefficient in May-July = 0.26 according to the Walter method over the years of research.

## 3 RESULTS

Research has shown that the studied factors had a significant impact on the yield and quality of rapeseed seeds.

First of all, it should be noted that more significant yield changes were associated with the introduction of mineral fertilizers. Without fertilizers, the yield of rapeseed was 1.04 t/ha, with the application of

$N_{23}P_{15}K_{23}S_2$, it increased to 1.50 t/ha or 0.46 t/ha (an increase of 44.2%). Against the background of $N_{47}P_{30}K_{46}S_5$ - 1.96 t/ha, which is 0.91 t/ha or 87.5% higher than the option without fertilizers.

Cover crops also had an impact on rapeseed yield. Rapeseed crops after winter cover crops reduced yields, which is explained by the large consumption of moisture by winter cereals both in autumn and spring, which negatively affected the development of rapeseed in the arid conditions of spring 2023.

We revealed an increase in rapeseed yield when placing it after a mixture of spring intermediate cover-ground crops, against a background without fertilizers by 0.09 t/ha, against a background of $N_{23}P_{15}K_{23}S_2$ - 0.17 t/ha and against a background of $N_{47}P_{30}K_{46}S_5$ - 0.19 t/ha, with an average value for fertilizer backgrounds of 0.15 t/ha or 10.3% (Table 2).

The evaluation of the effectiveness of the use of mineral fertilizers showed that for each kilogram of the active substance of fertilizers, from 5.13 to 7.38 kg of additional yield was formed, and when sowing spring intermediate cover-ground crops, the use of mineral fertilizers increased.

The dispersion analysis of the data obtained revealed the contribution of the studied factors to the formation of the rapeseed crop. Mineral fertilizers had the greatest impact – 92.9%, and cover crops – 3.8%.

Table 2: Yield of spring rapeseed depending on the norms of mineral fertilizers and sowing of intermediate cover-ground crops, t/ha (2023).

| Fertilisers (factor A) | Cover-ground crops (factor B) | On average | By factor A | By factor B |
|---|---|---|---|---|
| No fertilizers | Without cover-ground crops | 1.03 | 1.04 | - |
| | Spring cover-ground crops | 1.12 | | - |
| | Winter cover-ground crops | 0.98 | | - |
| $N_{40}P_{15}K_{23}S_2$ | Without cover-ground crops | 1.45 | 1.50 | 5.25 |
| | Spring cover-ground crops | 1.62 | | 7.38 |
| | Winter cover-ground crops | 1.44 | | 5.13 |
| $N_{80}P_{30}K_{46}S_5$ | Without cover-ground crops | 1.89 | 1.96 | 5.38 |
| | Spring cover-ground crops | 2.08 | | 6.56 |
| | Winter cover-ground crops | 1.90 | | 5.44 |
| LSD 05 for private various | | 0.11 | - | - |
| LSD 05 Factor A | | 0.06 | | |
| LSD 05 Factor B | | 0.06 | | |

Mineral fertilizers and cover crops not only influenced the yield, but also the quality of spring rape seeds (Fig. 1.).

The oil content of spring rape seeds decreased with increasing doses of mineral fertilizers, although the yield of vegetable fat from 1 ha increased due to higher yields. Cover crops contributed to the increase in this indicator, although the differences are within the error.

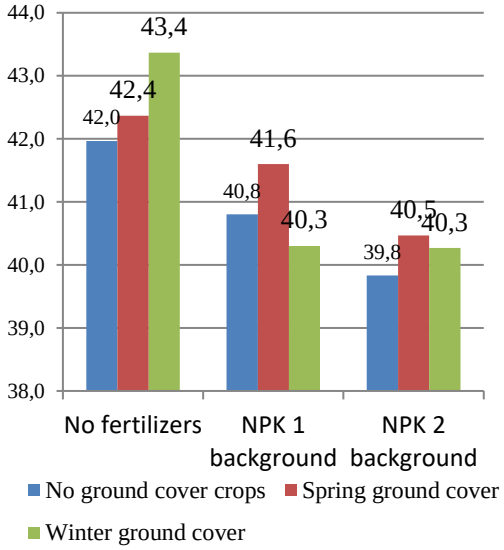



Figure 2: Vegetable fat content in spring rapeseed seeds, % per dry matter (LSD 05 for private various = 2.48; LSD 05 factor A = 1.43; LSD 05 factor B = 1.43).

# 4 DISCUSSION

No-till is the sowing of agricultural crops without plowing, seeds are introduced by special seeders for No-till in untreated soil – in stubble and plant residues of the previous crop. It is important to take into account that direct seeding should be considered only as a system, i.e. a technology that has its own characteristics. This technology is based on three basic principles: 1) refusal of any mechanical tillage, i.e. sowing is carried out on the stubble of the previous crop with a special seeder; 2) all plant residues from the previous crop are stored in the field and evenly distributed over the area; 3) strict alternation of agricultural crops (YUdin, Belobrov, Dridiger, Grebennikov, Ajdiev, Il'in, Ermolaev, 2019), we have proved that the technology is applicable in the conditions of the forest-steppe zone of the Middle Volga region, subject to all requirements.

In soil that has not been treated for many years, plant residues remain on its surface, which leads to the formation of a layer of mulch that protects the surface from erosion and creates a favorable temperature and humidity regime. In addition, with this technology, the economic component of agricultural production, its profitability, acquires special importance (Belobrov, YUdin, Ermolaev, Dridiger, Stukalov, Gadzhiumarov, 2018).

It is well known that when switching to direct seeding technology, the role of crop rotation increases (Mendis, Udawatta, Anderson, Nelson, Cordsiemon, 2022; Ivanov, Kulincev, Dridiger, Belobrov, 2021). One of the important conditions in this technology is compliance with the principle of crop rotation, which involves an annual change of crops from different economic and biological groups with significant differences in biology and cultivation technology. The change of crops in the crop rotation should be determined by the type of root system (fibroid or taproot), which will create conditions to meet the biological, physical and chemical reasons for the need for alternating crops in the crop rotation.

Using the example of rapeseed cultivation for seeds, we have proved that using the technology of No-till, cover crops improved the conditions for growth and development of the next crop in the crop rotation. When sowing a mixture of spring crops after harvesting the previous barley, the yield of the next rapeseed in the crop rotation increased from 0.09 t/ha or 8.7% (without fertilizers) to 0.19 t/ha or 10.1% (against the background of $N_{80}P_{30}K_{46}S_5$).

The greatest changes in yield were due to the use of mineral fertilizers, they made a significant contribution to increasing crop productivity, which is proven in rapeseed crops It should be noted that the combined use of mineral fertilizers and cover crops increased the use of fertilizers by plants for crop formation, which, in our opinion, is explained by the increased microbiological activity of the soil and their wider biological diversity.

When sowing winter cover-ground crops, there were no differences in productivity in comparison with the control variants of the next spring rapeseed. This fact is explained by the fact that the prolonged vegetation of winter crops reduced the content of productive moisture in the soil, the more the situation worsened in the conditions of drought, which manifested itself in the spring and summer of 2023.

# 5 CONCLUSION

Thus, in order to increase the productivity of spring rapeseed on the technology of No-till after harvesting the previous grain crops, it is necessary to sow spring cover crops, which, along with performing the functions of reproducing soil fertility (Tomashova, Osenniy, Ilyin, Veselova, 2021), increase the efficiency of the use of mineral fertilizers.

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# REFERENCES

Liebert, J., Mirsky, S. B., Pelzer, C. J., Ryan, M. R., ,2023. Optimizing organic no-till planted soybean with cover crop selection and termination timing. *Agronomy Journal*, 115, 1938–1956.

Tiefenbacher, A., Sandén, T., Haslmayr, H.-P., Miloczki, J., Wenzel, W., Spiegel, H, 2021. Optimizing Carbon Sequestration in Croplands: A Synthesis. Agronomy, 11, 882.

Ferreira, C.R., 2020. Claudia dos Reis; da Silva Neto, Eduardo Carvalho; Pereira, Marcos Gervasio; et al., Dynamics of soil aggregation and organic carbon fractions over 23 years of no-till management, Soil & Tillage Research, 198.

Dridiger, V.K., Stukalov, R.S., Gadzhiumarov, R.G., 2019. Vliyanie rastitel'nyh ostatkov na nakoplenie vlagi i populyaciyu dozhdevyh chervej pri vozdelyvanii polevyh kul'tur po tekhnologii No-till. Novye metody i rezul'taty issledovanij landshaftov v Evrope, Central'noj Azii i Sibiri: monografiya v 5 tomah. Tom IV. Optimizaciya sel'skohozyajstvennyh landshaftov. M.: izd-vo FGBNU «VNII agrohimii», 134–139.

Toigildin, A., Morozov, A., Podsevalov, M., Ayupov, D., 2020. et al., Factors of biologization of farming in the forest-steppe zone of Volga region, V sbornike: BIO Web of Conferences, 00173.

Mokrikov, G.V., Kazeev, K.SH., Akimenko, YU.V., i dr., 2017. Vliyanie tekhnologii no-till na ekologo-biologicheskoe sostoyanie pochv, Rostov-na-Donu, 140.

Hess, L-J.T , Hinckley, E-L.S., Robertson, G.P., Hamilton, S., Matson, P.A., 2018. Rainfall Intensification Enhances Deep Percolation and Soil Water Content in Tilled and No-Till Cropping Systems of the US Midwest. *Vadose zone journal,* 17, 1.

Dridiger, V.K., Belobrov, V.V., Stukalov, R.S., 2019. Rezul'taty issledovanij tekhnologii pryamogo poseva v zone neustojchivogo uvlazhneniya Stavropol'skogo Kraya. *Sel'skohozyajstvennyj zhurnal*, №S5(12), 51-59.

Blanco-Canqui, H., Wortmann, C.S., 2020. Does occasional tillage undo the ecosystem services gained with no-till? *A review, Soil & Tillage Research,* 198, 104534.

He, H., Chaolan, Zh., Qun, R., 2020. Effect of two organic amendments on atrazine degradation and microorganisms in soil. *Applied Soil Ecology,* 152, 103564.

Jemison, J.M., Welcomer, S., Kersbergen, R. , Majewski, C., 2018. Word cloud analysis of early adopter no-till farmer interviews. *Journal of Extension,* 56(3), #3RIB3.

Çelik, İ. Günal, H. Acar, M. et al., 2019 Strategic tillage may sustain the benefits of long-term no-till in a Vertisol under Mediterranean climate. *Soil and Tillage Research,* 185, 17-28.

Zavalin, A.A., Belobrov, V.P., Yudin, V.P., Dridiger, V.K., 2018. Nitrogen in chernozems under traditional and direct seeding cropping systems. A review, Eurasian Soil Science, 51, 12, 1497-1506.

YUdin, S.A., Belobrov, V.P., Dridiger, V.K., Grebennikov, A.M., Ajdiev, A.YA., Il'in, B.S., Ermolaev, N.R., 2019. K voprosu o metodike provedeniya mnogoletnih opytov po izucheniyu vliyaniya tekhnologii pryamogo poseva na svojstva pochv. *Byulleten' pochvennogo instituta im. V.V. Dokuchaeva*. № 98. s. 132-152.

Belobrov, V.P., YUdin, S.A., Ermolaev, N.R., Dridiger, V.K., Stukalov, R.S., Gadzhiumarov, R.G., 2018. Geografiya pryamogo poseva (No-till) v mirovom zemledelii V sbornike: Pochvy i zemel'nye resursy: sovremennoe sostoyanie, problemy racional'nogo ispol'zovaniya, geoinformacionnoe kartografirovanie. Materialy mezhdunarodnoj nauchno-prakticheskoj konferencii, posvyashchennoj 85-letiyu kafedry pochvovedeniya BGU i 80-letiyu so dnya rozhdeniya V.S. Anoshko. S. 198-203.

Mendis, S. S., Udawatta, R. P., Anderson, S. H.. Nelson, K.A., Cordsiemon, R. L., 2022. Effects of cover crops on soil moisture dynamics of a corn cropping system. *Soil Security,* Volume 8, 100072.

Ivanov, A.L., Kulincev, V.V., Dridiger, V.K., Belobrov, V.P. , 2021. Osvoenie tekhnologii pryamogo poseva na chernozemah Rossii. *Sel'skohozyajstvennyj zhurnal.* №2 (14). S. 18-36

Tomashova, O., Osenniy, N., Ilyin, A., Veselova, L., 2021.Ways to improve the reproduction of fertility of southern Shernozems V sbornike: E3S Web of Conferences. 14th International Scientific and Practical Conference on State and Prospects for the Development of Agribusiness, INTERAGROMASH 2021. Rostov-on-Don.