Role and significance of treatment in modern farming systems

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Abstract. The article deals with the influence of various methods of basic soil treatment on indicators of soil fertility and productivity of grain crop rotation crops at the experimental field of the Centre for precision farming. This center is based on the field experiment with the total area of about 6 hectares in the comparative study of precision and traditional farming technologies, as well as basic soil treatment techniques in a four-course crop rotation with alternating of crops: vetch and oat mixture for feed-winter wheat with stubble sowing of mustard for green manure-potatoes-barley. Two factors are studied in the experiment, namely technologies of field crops cultivation and methods of basic soil treatment. It is found that for most years, dump treatment was in the lead, primarily on a vetch and oat mixture and potatoes. The overall conclusion is that there are various degrees of manifestation interdependence between crops productivity and individual indicators of soil fertility, depending on treatment. The use of various agricultural methods that improve the rates of agrophysical, biological and agrochemical indicators will prevent the beginning of soil degradation in the field experiment of the center for precision farming and will stabilize soil characteristics at a sufficiently high level.

1. Introduction

Soil treatment is the most energy-intensive and expensive process in agricultural production. It costs 180-320 kWh/ha, or 50-80 kg of fuel per hectare. Soil treatment along with a positive effect has negative impact on its fertility. Thus, the use of heavy tractors and tools compacts arable and subsurface soil layers. Frequent loosening activates biological processes and mineralization of organic matter and leads to significant losses of nitrogen not used by plants and to decrease in soil humus content, as well as to development of erosion. Therefore, the development of more cost-efficient treatment technologies that significantly reduce energy costs is an important condition for modern farming [1, 2, 3].

With a high level of agricultural intensification, the functions of treatment change and its share in variation of yield does not exceed 8-12%. This is typical for soils with a high potential level of fertility and favorable agrophysical properties for plants. Under these conditions, the impact on soil can be minimized and the role of treatment can be reduced to the technological functions of embedding fertilizers, ameliorants, and pesticides. The main task is to maintain fertility reproduction, to regulate water and air regimes, and to protect soil from erosion [4, 5, 6].
Currently, soil treatment is no longer considered as an unavoidably expensive and poorly progressing part of farming systems. This component has become more mobile and dynamic in its development. Theory and practice of soil treatment for individual crops and crop rotations suggests new ways to solve complex problems of saving material and money costs, which in turn leads to increase in crops productivity and stabilization of soil fertility [7, 8].

Soil treatment along with crop rotations is the most important component of the farming system, as it determines intensity and cost of the latter, the level of anthropogenic load on the agricultural landscape and soil resistance to erosion, and the features of the machines and tools used in agricultural technologies [9, 10, 11].

2. Materials and methods
In 2007, as part of an innovative educational project at the Russian State Agricultural University – Moscow Agricultural Academy named after K. A. Timiryazev, the first scientific center for precision farming (CPF) was established in the country. This centre is based on the field experiment with the total area of about 6 hectares in the comparative study of precision and traditional farming technologies, as well as basic soil treatment techniques in a four-course crop rotation with alternating of crops: vetch and oat mixture for feed – winter wheat with stubble sowing of mustard for green manure – potatoes – barley. Two factors are studied in the experiment, namely technologies of field crops cultivation (Factor A) and methods of basic soil treatment (Factor B). Traditional technology is based on the use of modern equipment in compliance with the recommended parameters, deadlines and standard indicators of their implementation. Precision farming technology is based on the principles of using GPS satellite navigation system, which is used to modify implementation of farming practices. The studied methods of treatment differ in intensity and nature of impact on soil: dump, minimal and "zero" (direct sowing). This article is focused only on influence of various methods of soddy-podzolic low-productive soil treatment on its individual indicators and yield of crop rotation field crops [12, 13].

In modern conditions of crops cultivation in the CPF field experiment the following methods of compensating decrease of soil fertility are used: higher doses of mineral complex fertilizers (300-1000 kg/ha depending on crops) are introduced, mustard for green manure is sown after winter wheat harvesting, all crop and root mass is embedded into the soil. This ensures some stabilization of soil fertility and increase of the cultivated crops yield [14].

3. Results and discussion
On average over the years of research, potatoes and a vetch and oat mixture reacted to plowing better, winter wheat and barley formed relatively equal average yield for both treatments with the difference of 0.1 t/ha between them (Table 1).

The yield of vetch and oat mixture green mass at direct sowing exceeded the same at dump treatment in the first years of research (2012-2014) and in 2016. However, a number of collapse years, including 2017, 2019, and 2020, caused a new advantage of plowing in comparison with direct sowing, and averaged 2.8 t/ha over the years of research. Nevertheless, this situation allows talking about the possibility of cultivating a vetch and oat mixture as a fallow crop in the capacity of a forecrop with sowing at untreated soil.

For most years, productivity of winter wheat at plowing exceeded direct sowing. The exception is 2014, when winter wheat at dump treatment formed the yield 1.7 times less than at zero treatment due to significant drop in seedlings on the dump background because of frequent and heavy precipitation in autumn of 2013. However, the average crop yield for 9 years at plowing exceeds the same at zero treatment for 0.10 t/ha.

Potatoes have traditionally been the most productive at dump treatment. Over all the years of research, the yield of potato tubers at plowing exceeded this yield at minimal processing for 3.3 t/ha [5].
Table 1. Crops yield in CPF field experiment, t/ha.

| Soil treatment  | Yield by years, t/ha | Vetch and oat mixture for feed | Winter wheat | Potatoes | Barley |
|----------------|----------------------|--------------------------------|--------------|----------|--------|
|                |                      | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  | Average |
| Dump           | 20.6                | 22.1  | 24.5  | 31.2  | 25.3  | 22.8  | 13.8  | 7.6   | 22.6  | 21.2  |         |
| Zero           | 27.3                | 24.3  | 25.3  | 28.9  | 27.5  | 6.0   | 11.5  | 3.8   | 11.0  | 18.4  |         |
| LSD0.05, t/ha  | 3.10                | 2.0   | 0.83  | 3.07  | 3.10  | 4.35  | 2.20  | 2.8   | -     | -     |         |
| Dump           | 6.31                | 6.12  | 2.75  | 6.74  | 5.00  | 5.46  | 3.59  | 6.73  | 5.35  |        |         |
| Zero           | 6.15                | 5.87  | 4.59  | 6.73  | 5.52  | 5.13  | 4.83  | 2.55  | 5.96  | 5.25  |         |
| LSD0.05, t/ha  | 0.14                | 0.19  | 1.42  | 0.11  | 0.39  | 0.29  | 0.47  | 0.50  | 0.52  | -     |         |
| Dump           | 19.9                | 28.6  | 25.1  | 31.4  | 31.0  | 25.8  | 27.4  | 33.5  | 28.0  | 27.9  |         |
| Minimal        | 18.3                | 25.9  | 24.6  | 26.2  | 26.7  | 22.5  | 25.2  | 27.5  | 24.8  | 24.6  |         |
| LSD0.05, t/ha  | 0.56                | 0.16  | 0.90  | 1.08  | 2.11  | 2.28  | 1.79  | 2.12  | -     | -     |         |
| Dump           | 4.33                | 5.16  | 3.85  | 5.52  | 4.03  | 4.29  | 3.70  | 2.62  | 2.86  | 4.04  |         |
| Minimal        | 4.20                | 5.00  | 4.01  | 5.22  | 3.99  | 4.04  | 3.79  | 2.76  | 2.48  | 3.94  |         |
| LSD0.05, t/ha  | 0.90                | 0.13  | 0.17  | 0.28  | 0.19  | 0.16  | 0.11  | 0.14  | 0.25  |        |         |

The effect of dump and minimal treatments on barley yield is ambiguous. Only in some years, there was a slight advantage for minimal treatment, but in most years, excess of yield on the dump background was noted, in this regard, the difference between the options was on average 0.10 t/ha in favor of dump treatment.

The comparison of the experiment options for agrophysical indicators of soil fertility supports the options for which slightly larger productivity data was obtained. This situation concerns, first of all, water content in soil, its density and hardness.

Slightly more moisture on average over the years of research was contained at zero treatment as compared to plowing for the first two crops of the crop rotation, and there were differences with an excess at dump treatment only for the two closing crops. Density of soil composition in most cases corresponded to the optimal indicators for crops or slightly exceeded them. Higher rates of density and hardness of soddy-podzolic soil for all crops were achieved at minimal, especially at zero treatment.

A visual representation of soil hardness spatial distribution under winter wheat is Figure 1. The minimal and zero options were characterized by higher soil hardness, but such differences with plowing were not significant in terms of their impact on productivity of field crops [6].
| Soil layer, cm | Location for identification | Soil hardness, kPa |
|---------------|-----------------------------|-------------------|
| 1             | Sowing                      | ![Sowing Map]     |
| 0-10          | Row spacing                 | ![Row Spacing Map]|
|               | Track                       | ![Track Map]      |

Soil treatment:
- zero
- Dump
4. Conclusion
The comparative analysis of crop yield interdependence and the content of humus and nutrients in soil confirms the conclusion that the highest content of organic matter is in the option of minimal treatments. When comparing the humus content under potatoes and barley, the indicators were leveled. If the difference in terms of humus content is 0.05% in favor of direct sowing on annual grasses and winter wheat, then potatoes and barley already have an advantage of plowing for 0.02%. The differences in the content of nutrients in soil under the crops are also ambiguous. The contrast between the options of a vetch and oat mixture with an advantage of zero treatment is more obvious, and dump treatment should be highlighted for potatoes.
5. Acknowledgments
The overall conclusion is that there is various degrees of manifestation interdependence between crops productivity and individual indicators of soil fertility, depending on treatment. The use of various agricultural methods that improve the rates of agrophysical, biological and agrochemical indicators will certainly prevent the beginning of soil degradation in the field experiment of the centre for precision farming and will stabilize soil characteristics at a sufficiently high level.

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