Influence of tillage methods on crop productivity in the second rotation of crop rotations

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Abstract. The article presents the results of studying the minimum methods of soil cultivation in a stationary experiment on the gray forest heavy loam soil of the southern part of the Volga-Vyatka region of Russia. Based on the conducted research, it was found that on gray forest soils in adaptive landscape agriculture of the Chuvash Republic, it is advisable to replace the traditional method of soil cultivation (based on dump plowing) with resource-saving methods. This is primarily the use of minimum-1 and 2 methods of soil treatment, where combined tillage units KOS-3 and BDM-4-3.2 are used.

1. Introduction
Currently, farmers face more acute problems of resource conservation, ecology, profitability of production, preservation and improvement of soil fertility. Under these conditions, the issues of soil cultivation, plant care, and use of post-harvest plant residues, accumulation and conservation of soil moisture, control of diseases, plant pests and weeds, and protection of soils from water erosion are raised in a new way. The transition to resource-saving technologies of soil cultivation is caused by a sharp increase in the cost of material and technical means produced by the industry, as well as high prices for fuel and lubricants. Cost reduction in the cultivation of agricultural crops is achieved by replacing ploughing with non-fallow loosening, reducing or combining operations during spring processing [1, 2].

The annual use of dump methods of soil treatment requires large expenditures of energy resources and labor, so it does not fully meet modern ideas about resource-saving technologies for cultivating agricultural crops [3]. In the conditions of the right Bank of the Volga river of the Volga-Vyatka region of Russia, where intensive water-erosion processes occur on the arable land, plowing contributes to the flushing of the soil during periods when the field surface is not occupied by a closed plant mass. Piled and split furrows formed when plowing by the corral method stimulate the development of trickle erosion on the arable land, and the Shuttle plowing method is possible only in the presence of turning and turning plows, which have not yet found wide distribution.

The main treatment (plowing) of the soil, while remaining the most energy-intensive and long-term method in the cultivation technology, still does not sufficiently meet the requirements of maximum moisture accumulation and moisture conservation, energy conservation, and does not meet the requirements of sparing impact on the soil and the environment. The main direction of improving the soil treatment system is its adaptation to specific soil climatic conditions, cultivated crops, types and types of crop rotations [4, 5].
Minimum soil protection treatment is one of the most important methods of energy saving in agriculture, and the concept of minimum treatment should be developed as a natural and soil protection [6, 7]. To identify the most effective ways of the basic minimum tillage compared to traditional cultivation in the major grain and leguminous crops, potatoes in crop rotations with a clean and sidereal in the Chuvash Research Agricultural Institute – Branch of “Federal Agricultural Research Centre of the North-East named N.V. Rudnitskogo” is held stationary two-factor experience. Where the study is widely used in the Chuvash Republic minimum methods of basic soil cultivation: classic or traditional (control), minimum-1, minimum-2 and minimum-3 in two field crop rotations on gray forest soil.

The purpose of the research is to identify the influence of minimal methods of soil treatment on water-air regimes and agrophysical properties of the soil.

2. Materials and methods
The research was conducted according to the guidelines for conducting scientific research in agriculture, crop production and Agrochemistry [8].

In order to identify the most effective minimal methods of basic tillage in comparison with traditional cultivation of main grain and leguminous crops, potatoes in crop rotations with pure and sidereal, a two – factor stationary experiment is conducted in the Chuvash Research Agricultural Institute – Branch of the FANC North-East (table 1). Where we study the most widespread in the Chuvash Republic minimum methods of basic tillage: classic or traditional (control), minimum-1, minimum-2 and minimum-3 in two field crop rotations on gray forest soil.

| №  | Grain crop rotation       | Grain-pasture sidereal crop rotation |
|----|---------------------------|-------------------------------------|
| 1. | Spring wheat             | Spring wheat + clover               |
| 2. | Pure steam               | Clover (green manure)              |
| 3. | Winter wheat             | Winter wheat                       |
| 4. | Potato                   | Potato                              |
| 5. | Barley                   | Barley                              |
| 6. | Spring vic               | Spring vic                          |

The second factor. V methods of basic tillage in crop rotations:
1. Classic (traditional) – PLN-3-35 (autumn processing), coupling with BZT-1.0 (harrowing), Pauk-6 - (spring) control;
2. Minimum-1 – KOS-3.0 (autumn), BZT-1.0, Pauk-6 (spring);
3. Minimum-2 – BDM-3, 2x4 (autumn), BZT-1.0, Pauk-6 (spring);
4. Minimal-3 – (without autumn processing), BZT-1.0, Pauk-6 (spring).

The stationary experiment is located on the weakly morphological slope of the North-Eastern exposure with a weakly expressed microrelief. The soil of the experimental site is gray forest, heavy loam, slightly washed on loess-like cover loam. Humus content-5.5 %, mobile phosphorus-125 mg / kg, exchange potassium – 146 mg / kg, soil acidity – 5.3.

The traditional or classic method of tillage is a control option. Agricultural techniques for cultivating crops in crop rotations are generally accepted for the natural and climatic conditions of the Chuvash Republic in Russia [5], with the exception of the studied treatments. Grinding of by-products is mandatory. The unit Pauk-6 carried out pre-sowing tillage to a depth of 6 cm. Herbicides were used against weed vegetation. Made fertilizers under crops: according to N₄₀P₄₀K₄₀, under potatoes N₆₀P₆₀K₆₀ [6].

Agrometeorological conditions in the years of the study had a big difference; in 2012 and 2013, the temperature regime and soil moisture conditions were good; 2014, 2015 and 2016 were dry, and in 2017, there was an excess of moisture.
3. Results
Minimum-2 variants of tillage resulted in lower yields of spring wheat in crop rotations by 0.38 t/ha, while minimum-3 it decreased by 0.53 and 0.59 t/ha (table 2). The highest yield of spring wheat (4.18-4.33 t/ha) in 2012 were received grain crop rotation rotation in classical and minimum-1 method of tillage.

The highest yield of winter wheat grain in 2014 was on both crop rotations with classic, minimum-1 and minimum-2 variants of soil treatment. Where its yield was in the grain crop rotation from 3.96 to 4.14 t/ha, and in the grain crop rotation it was in the range from 4.05 to 4.23 t/ha (table 2). During these treatments, the productivity of winter wheat was at the same level, or the difference is within the error of experience.

Table 2. Crop yield in the first and second rotation of crop rotations by processing methods, t/ha.

| Processing method | Spring wheat 2012 year | Winter wheat 2014 year | Potato 2015 year | Barley 2016 year | Spring vetch 2017 year |
|-------------------|------------------------|------------------------|-------------------|-----------------|------------------------|
| **Grain crop rotation** |                        |                        |                   |                 |                        |
| 1. Classic        | 4.24                   | 4.14                   | 22.7              | 3.96            | 2.53                   |
| 2. Minimum-1      | 4.18                   | 4.08                   | 17.7              | 3.92            | 2.26                   |
| 3. Minimum-2      | 3.86                   | 3.96                   | 16.1              | 3.64            | 2.11                   |
| 4. Minimal-3      | 3.71                   | 3.78                   | 13.3              | 2.98            | 2.07                   |
| **Grain-pasture sideral crop rotation** |                        |                        |                   |                 |                        |
| 1. Classic        | 4.33                   | 4.23                   | 24.3              | 4.04            | 2.65                   |
| 2. Minimum-1      | 4.28                   | 4.12                   | 18.4              | 3.99            | 2.33                   |
| 3. Minimum-2      | 3.95                   | 4.05                   | 17.1              | 3.77            | 2.28                   |
| 4. Minimal-3      | 3.74                   | 3.88                   | 14.7              | 3.13            | 2.17                   |

The minimum-3 method of processing in crop rotations led to a decrease in yield. In the grain crop rotation, it decreased by 0.36 t/ha or 9.1% compared to plowing, in the grain crop rotation by 0.35 t/ha or 8%.

The maximum yield of potatoes in both crop rotations in natural and climatic conditions in 2017 was under the classic version of soil cultivation, where its yield was 22.7 t/ha in the grain crop rotation and 24.3 t/ha in the seed crop rotation. The minimum-1 and minimum-2 methods of tillage led to a decrease in potato yield in crop rotations: by 5.6 and 5.9 t/ha with a minimum-1, by 5.6 and 7.1 t/ha with a minimum-2. The minimum-3 method of tillage in crop rotations led to the greatest reduction in yield. In the grain crop rotation, it decreased by 9.4 t/ha or 41%, in the grain-lateral crop rotation by 9.6 t/ha, i.e. by 40%.

The highest yield of barley in both crop rotations was in the classic version of tillage, where its yield was 3.96 t/ha in the grain crop rotation, and 4.04 t/ha in the grain crop rotation. The minimum-1 and 2 variants of tillage led to a decrease in the yield of barley in crop rotations: by 0.22 and 0.27 t/ha. The minimum-3 system of tillage in crop rotations led to the greatest reduction in yield. In the grain crop rotation, it decreased by 0.98 t/ha or 25%, in the grain crop rotation by 0.91 t/ha, i.e. by 23%. The best indicators of productivity of spring vetch in both crop rotations were in the classic version of soil cultivation, where its yield was 2.53 t/ha in the grain crop rotation, and 2.65 t/ha in the grain crop rotation. Minimal tillage options resulted in reduced vetch yields in crop rotations from 0.27 to 0.48 t/ha.
The results of dispersion analyses showed that the yield of agricultural crops in crop rotations was significantly affected only by the methods of soil treatment (F05 less than FF), and the types of crop rotations and their interaction with soil treatment options did not significantly affect:

1. NSR05 for factor A= 0.12 t / ha, NSR05 for factor B=0.14 t / ha – for cereals;
2. NSR05 for factor A= 1.15 t / ha, NSR05 for factor B=0.34 t / ha – for potatoes.

The best results of economic efficiency were obtained in the cultivation of spring wheat, winter wheat, and barley, when the minimum-1 method of tillage was used. Where the profitability of production of these crops is from 7% to 16% higher than in the control, with a production profitability of 53-65 % (table 3).

**Table 3.** Profitability of crop cultivation during the second rotation of crop rotations by processing methods, %.

| Processing method          | Spring wheat | Winter wheat | Potato | Barley | Spring vetch |
|----------------------------|--------------|--------------|--------|--------|--------------|
|                           |              |              |        |        |              |
| Grain crop rotation        |              |              |        |        |              |
| 1. Classic (traditional)   | 41           | 44           | 88     | 53     | 68           |
| 2. Minimum-1               | 57           | 53           | 59     | 65     | 75           |
| 3. Minimum-2               | 37           | 40           | 49     | 50     | 66           |
| 4. Minimal-3               | 25           | 28           | 29     | 31     | 66           |
| Grain-pasture sideral crop rotation | | | | | |
| 1. Classic (traditional)   | 46           | 46           | 97     | 56     | 69           |
| 2. Minimum-1               | 58           | 53           | 64     | 69     | 77           |
| 3. Minimum-2               | 41           | 41           | 56     | 53     | 69           |
| 4. Minimal-3               | 27           | 32           | 39     | 36     | 67           |

The minimum-2 processing option is inferior to the classic method, i.e. by 2-5 %. The minimum-3 method of processing significantly worsened the main economic indicators, when it was used, the economic efficiency of these treatments decreased from 16 to 21 %.

When cultivating potatoes, the best results of economic efficiency are obtained in the system of tillage, where the classic method (plowing) was used. Here, the profitability of potato production was the best and amounted to 88 % in the grain crop rotation, and 97 % in the grain crop rotation. With the minimum-1 method, the profitability was 59 and 64 %, respectively, with the minimum-2 – 49 and 56 %, and with the minimum-3 method only – 29 and 39 %.

Replacing the classic method of tillage with minimal methods did not worsen the main economic indicators when cultivating spring vetch in the natural and climatic conditions of 2017. The best results of economic efficiency were obtained in the variants of tillage using the minimum-1 method, where the profitability was 68 % in the grain – pasture crop rotation, 69 % in the grain – pasture sideral, i.e. higher by 7 and 8 % than when plowing. When using the minimum-2 and minimum-3 methods of tillage, the indicators of economic efficiency (profitability) are the same as when plowing. The productivity of tillage aggregates with combined processing methods increases from 2.2 to 3.5 times.

**4. Conclusions**

The highest yield of all cultivated crops in crop rotations was obtained when used in variants when plowing was used. For cereals, it was 3.96-4.33 t / ha, for spring vetch-2.5-2.6 t / ha, for potatoes-22.7-24.3 t / ha.

The best results of economic efficiency from the use of various methods of tillage in the cultivation of cereals and legumes were obtained in the minimum-1 variant. Where the profitability of production was 53-77 % in crop rotations, i.e. 8-16 % higher than when plowing. With a minimum-2 method of
processing, the profitability is the same as when plowing. When cultivating potatoes, the best results of economic efficiency are obtained in the system of tillage, where the classic method (plowing) was used. Here, the profitability of potato production was the best and amounted to 88 % in the grain crop rotation, and 97 % in the grain crop rotation. With the minimum-1 method, the profitability was 59 and 64 %, respectively, with the minimum-2 – 49 and 56 %, and with the minimum-3 method – 29 and 39 %.

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