Influence of cultivation technologies of agricultural crops with the use of machines and tools of domestic and foreign production for the dry area of the South of Russia

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Abstract. The problems of improving the tillage systems and crop cultivation technologies are of particular relevance both in terms of energy savings and, in general, resource conservation. The article describes various tillage systems using machines and implements of domestic and foreign production for the arid zone of southern Russia. The initial position in the development of cultivation technology of crops are agroecological requirements of the crop and variety to the growing conditions. Sequential overcoming of factors that reduce crop yields and product quality allows us to form the most optimal growing technology for specific climatic conditions of the economy. The article describes the tillage systems - moldboard, resource-saving using domestic tillage equipment, resource-based on foreign technology and recommended using combined technology, which has different effects on the conservation and accumulation of productive moisture. With the moldboard tillage, these indicators are the smallest, and resource-saving systems give approximately the same results when determining the stock of productive moisture in all phases of crop development. Different tillage systems for crop rotation affect the agrophysical indicators of fertility - aggregate composition, water strength, structural coefficient to the same extent. Moldboard tillage system causes the lowest density of soil in the cultivation of crop rotation in comparison with various resource-saving systems, as for the porosity of the soil, in most cases, these indicators of large values are marked by moldboard tillage. Resource-saving tillage systems significantly complicate the phytosanitary situation in the cultivation of crop rotation in comparison with the moldboard tillage system.

Improvement of tillage systems and crop cultivation technologies are of particular relevance from the point of view of energy savings, and, in general, resource conservation. The main reserve of energy saving is the improvement of tillage. In recent years, various ways have been proposed to minimize this energy-intensive process. Recommendations on the transfer of farming to preservative tillage in the south of Russia have not yet received sufficient scientific and industrial verification. However, it is clear that this transition will require a complete change of the adopted farming systems. It is associated with long terms of development, replacement of all equipment, mainly with imported equipment, and, therefore, large economic and social costs are inevitable during the transition period. Resources need to be saved now and, preferably, at the expense of domestic developments and equipment.

In this regard, in the conditions of Experimental Production Farm «Lucho» Ltd., Novoselitsky district, in 2013-2017, field multifactorial stationary experience was laid in the eight-field grain-and-fallow crop
rotation to determine the impact of resource-saving soil-protective technologies of crop cultivation on soil fertility factors and crop yields in the arid zone of the Stavropol Territory.

Objective: conducting research to study the resource-saving soil-protection pre-sowing tillage in various technologies of agricultural crops cultivation using machines and implements of domestic and foreign production for the arid zone of the Stavropol Territory.

As a result of the studies, the influence of various technologies on the water, physical and agrochemical indicators of soil fertility was studied; yield and productivity of crop rotation; economic effectiveness of the studied techniques.

The selection of soil and plant samples was carried out in the main phases of crop development.

Soil tilling was carried out by domestic and foreign equipment, which allowed us to make comparison.

There was triple repetition of the experiment and systematic plot arrangement. One plot of land was 35 hectares; registration plot was 33 hectares.

The following field crop cultivation technologies were studied in the experiment:

- Moldboard (control).
- Resource-saving technology based on domestic equipment.
- Resource-saving technology based on foreign equipment.
- Resource-saving technology, recommended by scientific institutions of the region.

According to the schematic course of experiment, cultures of crop rotation were cultivated in these fields:

- Fallow black
- Winter wheat
- Winter wheat
- Peas for grain
- Winter wheat
- Maize for silage
- Winter barley
- Sunflower

Crop change on the fields of production experiment was conducted in strict accordance with their placement in crop rotation.

| Year | Field 1            | Field 2       | Field 3         |
|------|--------------------|---------------|-----------------|
| 2013 | Maize for silage   | Sunflower     | Winter wheat    |
| 2014 | Winter barley      | Black fallow  | Winter wheat    |
| 2015 | Sunflower          | Winter wheat  | Peas for grain  |
| 2016 | Black fallow       | Winter wheat  | Winter wheat    |
| 2017 | Winter wheat       | Peas for grain| Maize for silage|

Technological schemes of soil tillage system:

1. Moldboard technology:
   1.1. Disk plowing with disk tiller (BDK-4) to a depth of 6-8 cm.
   1.2. Tillage with mounted plough (PLN-8-35) to a depth of 20-22 cm.
   1.3. Cultivation to a depth of 6-10 cm.
   1.4. Seeding with drill seeder (SZ-3.6).
2. Resource-saving technology based on domestic equipment:
2.1. Tilling with soil-tilling and planting combine (APP-7,2) to a depth of 8-10 cm.
2.2. Cultivation to a depth of 6-10 cm.
2.3. Seeding with drill seeder (SZ-3.6).

3. Resource-saving technology based on foreign equipment:
3.1. Disk tiller («Rubin») to a depth of 6-8 cm.
3.2. Machinery unit («Lemken») to a depth of 8-10 cm.
3.3. Seeding with drill seeder (SZ-3.6).

4. Resource-saving technology, recommended by scientific institutions of the region:
4.1. Tilling with soil-tilling and planting combine (APP-7,2) to a depth of 8-10 cm.
4.2. Field cultivator (KPS-4) to a depth of 6-8 cm.
4.3. Seeding with drill seeder (SZ-3.6).

Resource-saving technology based on domestic equipment provides a reduction in the structural state of the soil, which indicates a strong mechanical effect of these soil-forming tools, which results in a decrease in the structural state by 7.1% compared to the soil tilled by resource-saving technology based on foreign equipment. As for the recommended technology, it is close to the indicators using foreign equipment.

The condition of the soil in the cultivation of winter wheat in the phase of tillering by moldboard technology, the number of agronomically valuable aggregates is 31.5%.

This is one of the lowest indicators, which indicates a very low structural state. The structure index in this variant is only 0.8. The use of resource-saving technology based on foreign equipment provides a structural state of 48.4 and the structure index is, respectively, 0.9.

The lowest structural condition of the soil was formed when applying the recommended technology, which is 29.4%. Resource-saving technology based on domestic equipment is significantly inferior to foreign and is 44.8%.

In the phase of full ripeness, indicators of the structural state of the soil according to moldboard technology increase when using resource-saving technologies on the basis of both domestic and foreign equipment and increase compared to the state before winter wheat sowing.

As for the influence of the studied technologies, the use of resource-saving technologies based on foreign equipment provides a more favorable structural state than the domestic one.

Resource-saving technology based on domestic tillage equipment, since the impact on the soil is carried out only on its surface layers, has led to the greatest indicators of water resistance of soil aggregates during the entire growing season of winter wheat [1].

Resource-saving technologies, especially with the use of foreign equipment, provide the most favorable conditions for filling and absorbing moisture, the activity of soil biota and for growing plants. Resource-saving technology of tilling black fallow with the use of foreign equipment in these agrosoil conditions is most suitable for agricultural production [2,4].

Table 2. The impact of crop and fallow cultivation technologies on potential soil contamination, mln. pcs/ha (average for 2013-2017).

| Culture          | Cultivation technology     | Soil layer, cm |
|------------------|---------------------------|----------------|
|                  |                           | 0-10  | 10-20 | 20-30 | 0-30 |
| Black fallow     | Moldboard (control)       | 45.9  | 70.3  | 52.6  | 168.8|
|                  | Resource-saving technology based on domestic equipment | 101.1 | 79.9  | 71.6  | 252.6|
|                  | Resource-saving technology based on foreign equipment | 98.6  | 75.7  | 68.1  | 242.4|
Methods of primary tillage clearly affect on the presence and distribution of seeds and vegetative buds of weeds in the arable layer. According to experimental data, resource-saving (domestic) and resource-saving (foreign) tillage contribute to seed accumulation, both in a layer of 0-30 cm and in the top layer of 0-10 cm. Thus, up to 50% of the total stock of weed seeds is in the most favorable conditions for germination. This pattern is seen in all studied previous crops. The moldboard method of main tillage, on the contrary, helps to clean the soil, which is explained by the displacement of weed seeds to a depth of more than 10 cm, thereby making it difficult for them to germinate and increase mortality.

The results of determining the potential contamination depending on the previous crop and the way of the main tillage state the fact that the biological characteristics of agricultural crops and the characteristics of agricultural engineering, fundamentally affect the preservation and accumulation of seeds and vegetative rudiments of weeds in the soil, which ultimately has a direct influence on the formation of a completely defined agrophytocenosis [3, 5].

In the practice of using mineral fertilizers, the agrochemical characteristics of the soil are of great importance, from which it is possible to draw conclusions about the real degree of plants provision with mobile nutrients (table 3).
As can be seen from the data presented in the table, the reaction of the soil solution remained almost unchanged compared with the initial indicators and is included in the alkaline group.

The average concentration of mobile phosphorus in 2013 was 23–25 mg/kg of soil, in 2017 - 17–19 mg/kg of soil. It should be noted that the availability of phosphorus in the soil in the analyzed period of time corresponds to the average group. However, in 2017, there is a decrease in mobile phosphorus compared with baseline indicators for all variants of experience.

Table 3. Agrochemical characteristics of the soil according to the cultivation technology of crops in Experimental Production Farm «Luch» Ltd., Novoselitsky district, 2013/2017.

| Culture          | Cultivation technology                   | PH water | Soil content, mcg/kg | N-NO₃ | P₂O₅ | K₂O |
|------------------|------------------------------------------|----------|----------------------|-------|------|-----|
|                  |                                           | 2013     |                      |       |      |     |
|                  | Moldboard (control)                       | 8,20     | 22                   | 24    | 391  |
|                  | Resource-saving technology based on domestic equipment | 8,20 | 21 | 23 | 384 |
| Maize for silage | Resource-saving technology based on foreign equipment | 8,20 | 20 | 25 | 400 |
|                  | Resource-saving technology, recommended by scientific institutions of the region | 8,20 | 26 | 24 | 395 |
|                  |                                           | 2017     |                      |       |      |     |
|                  | Moldboard (control)                       | 8,07     | 17                   | 19    | 381  |
|                  | Resource-saving technology based on domestic equipment | 8,11 | 12 | 17 | 370 |
| Winter wheat     | Resource-saving technology based on foreign equipment | 8,10 | 13 | 18 | 373 |
|                  | Resource-saving technology, recommended by scientific institutions of the region | 8,09 | 14 | 19 | 380 |

The effect of the cultivation technologies being studied on the content of exchangeable potassium in the soil had a similar dependence as in the content of mobile phosphorus. On average, in 2013, the content of exchangeable potassium is 393 mg/kg of soil, and in 2017, 373 mg/kg of soil, which corresponds to the grouping with an increased content of this element in the soil during the analyzed period of time. In all variants of the experiment, the content of exchangeable potassium in 2017 was lower compared with the initial indicators.
Thus, resource-saving technologies have a positive effect on the agrophysical factors of soil fertility (productive moisture, total and capillary porosity), which should have a positive impact on the quantity and quality of crops grown. Moldboard technology has the greatest phytosanitary effect on the soil. Resource-saving technologies lead to a significant complication of the phytosanitary condition, which requires the use of herbicides.

The reaction of the soil solution has remained almost unchanged compared with the initial indicators and is included in the alkaline group. The average concentration of mobile phosphorus in 2013 was 23–25 mg/kg of soil, in 2017 - 17–19 mg/kg of soil. It should be noted that the availability of phosphorus in the soil in the analyzed period of time corresponds to the average group. However, in 2017, there is a decrease in mobile phosphorus compared with baseline indicators for all variants of experience.

All the cultivation technologies being studied reduced the average productivity of crop rotation as compared with the control over the studied period of time. At the control, the average productivity of the crops was 3.60 t/ha grain unit and it was higher than the efficiency of resource-saving cultivation technology based on domestic equipment (machinery) by - 0.18 t/ha grain unit, resource-saving cultivation technology based on foreign equipment (machinery) by - 0.23 t/ha grain unit and resource-saving technology recommended by scientific institutions of the region by - 0.12 t/ha grain unit. It should be recognized that the difference between the productivity of crops in the crop rotation of the studied variants was insignificant, since it was within the limits of experimental error. Among the resource-saving technologies, the highest productivity was achieved on the variants using the cultivation technology recommended by the scientific institutions of the region, and amounted to 3.48 t/ha grain unit, which was almost on a par with the productivity on the variants using the resource-saving technology based on domestic equipment - 3.42 t/ha grain unit, and exceeded productivity on variants with cultivation technology based on foreign equipment by - 0.11 t/ha grain unit. According to the results of many years of research, it can be concluded that from the agrotechnical point of view, all the cultivation technologies under study, compared with the control, did not significantly reduce the productivity of crop rotation. At the control, the applied moldboard soil tillage provided on heavy loam ordinary chernozem in the arid zone of the Stavropol Territory, the average crop productivity of the crop rotation is 3.60 t/ha, which is 0.12-0.23 t/ha higher than the compared resource-saving technologies of crop cultivation. Among the resource-saving technologies, the highest productivity was achieved on the variants using the cultivation technology recommended by the scientific institutions of the region, and amounted to 3.48 t/ha grain unit. It was established that the difference between the productivity of the crop rotation of the studied variants was insignificant, and was within the limits of experimental error.

The use of moldboard technology of crop cultivation in crop rotation in the arid zone on heavy loamy chernozem contributed to maximizing the productivity of cultures in crop rotation per unit area - 3.6 t grain unit, which is 3-7% higher than similar indicators of resource-saving technologies.

References
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