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Resource-saving tillage technologies and their impact on grain crop yields

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Abstract. The work is devoted to analysing the efficiency of resource-saving tillage technologies, namely minimum and zero tillage, in the cultivation of grain crops. Experimental work was carried out in different agro-climatic zones, using conventional, minimum and zero tillage. The influence of different tillage systems on yield, economic indicators of production and agrophysical properties of soil was studied. It was found that minimum tillage provides higher yield of grain crops compared to traditional ploughing, as well as improves soil structure, increases its biological activity and reduces fuel costs. Zero tillage in case of observance of technologies provides yield at the level of traditional tillage. The necessity of further study and adaptation of resource-saving technologies to specific soil and climatic conditions in order to achieve maximum economic and environmental efficiency has been revealed. The results emphasise the prospects of minimum tillage for sustainable agricultural development.

1 Introduction

Intensive agricultural practices involving deep tillage lead to a range of negative consequences such as soil erosion, reduced soil fertility, deterioration of water regimes and environmental pollution. These problems not only threaten the sustainability of agricultural systems, but also have a significant impact on global environmental processes, including climate change and biodiversity loss. Recognising the seriousness of the situation, the global community is actively seeking alternative approaches to agriculture aimed at reducing negative environmental impacts while ensuring stable yields. When considering land use issues, an important role is played by taking into account the influence of climatic factors [1, 2].

One of the promising directions in solving these problems is the introduction of resource-saving tillage technologies, such as minimum and zero tillage [3, 4]. These approaches, in contrast to traditional methods, involve reducing the depth and intensity of mechanical impact on the soil, which contributes to preserving its structure, improving the water-air regime and reducing the risk of erosion. At the same time, an important advantage is the reduction of fuel and labour costs [5, 6]. Nevertheless, such technologies are not without certain disadvantages. For example, minimum and zero-tillage require more careful control of field weediness, which can lead to increased herbicide costs. In addition, switching to new technologies requires revision of existing agronomic approaches and adaptation to specific soil and climatic conditions. Other approaches include the use of organic fertilisers and siderates [7, 8], integrated plant protection, as well as the introduction of crop rotations and reclamation measures. Each of these directions has its advantages and disadvantages, which should be carefully analysed when implementing them.

It is in the context of the search for ways to improve the efficiency and sustainability of agrarian systems that the direction of resource-saving agriculture with minimisation of soil tillage becomes particularly relevant. The introduction of such technologies is an important step towards the creation of ecologically more sustainable and economically efficient agro-ecosystems that can ensure food security in the long term and preserve natural resources for future generations [9, 10]. At the same time, it is important to identify the criteria of ecological and economic feasibility and assess the effectiveness of the introduction of these technologies in real economic conditions. The search for optimal parameters of minimising tillage, providing stable yields at minimum costs, is an important and urgent task.

The purpose of this work is to study the scientific experience of applying resource-saving technologies of minimising tillage in the cultivation of grain crops. Within the framework of the work, the analysis of existing studies aimed at determining the effectiveness of minimum and zero tillage, as well as identifying factors affecting its application in different agro-ecological conditions was carried out. Particular attention was paid to analysing the responsiveness of different types of grain crops to this type of treatment, with the identification of the main advantages and disadvantages [11, 12]. Based on the analysis,

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conclusions and recommendations for further improvement of resource-saving technologies were formulated.

2 Method and materials

The experiments were conducted on several experimental plots located in different agro-climatic zones, taking into account the variability of soil types and weather conditions.

The research compared conventional tillage methods with minimum and zero tillage, as well as various combinations of these approaches.

A wide range of agricultural equipment was used for experimental work.In the variant with traditional tillage the plough PLN-4-35 was used, providing ploughing to a depth of 20-22 cm. The working speed of the machine was 7-8 km/h, with a working width of 1.4 metres.KPS-4 cultivator was used for surface tillage, which provided soil loosening to a depth of 8-10 cm.The working speed of the cultivator was 9-10 km/h.Based on the analysis, conclusions and recommendations for further improvement of resource-saving technologies were formulated.

To prepare the seedbed after ploughing, a combined aggregate AKR-3 was used, which loosened, levelled and compacted the soil in one pass. In variants with minimum tillage disc harrows BDT-3 and cultivators KPS-4 were used at a shallower depth - 5-7 cm, excluding deep ploughing. In the variant with zero tillage immediately before sowing Amazone DMC-6 direct seeding complex was used, which provided sowing of seeds without pre-tillage. All sowing was carried out by grain seeder SZ-3.6. Seed sowing and fertiliser application rates were in accordance with recommendations for each specific crop and soil-climatic conditions. In the course of research, the yield was monitored, and the economic efficiency of different cultivation technologies was analysed, taking into account the costs of fuel, fuels and lubricants, labour, seeds, fertilizers and plant protection products.

3 Results and discussion

The presented research was aimed at a comprehensive study of the effectiveness of different tillage systems in the cultivation of grain crops, with a special emphasis on resource-saving technologies.

To achieve this goal, a number of experimental works were carried out, including comparison of conventional, minimum and zero tillage. The experiments were organised on several experimental plots located in different agro-climatic zones, taking into account the diversity of soil cover and climatic conditions.

In the course of research, the influence of different tillage systems on grain crop yields, economic indicators of production, as well as on agrophysical properties of soil was studied.

In the framework of the experimental study, on the control plots the traditional tillage system was used, which included autumn ploughing with plough PLN-4-35 to a depth of 20-22 cm followed by cultivation with cultivator KPS-4 to a depth of 8-10 cm in spring and harrowing with disc harrow BDT-3 to a depth of 6-8 cm to prepare the seed layer.KPS-4 cultivator was used for surface tillage, which provided soil loosening to a depth of 8-10 cm.The working speed of the cultivator was 9-10 km/h.BDT-3 disc harrow was used with working speed of 10-12 km/h and cultivation depth of 6-8 cm.To prepare the seedbed after ploughing, a combined aggregate AKR-3 was used, which loosened, levelled and compacted the soil in one pass.

Sowing was carried out in optimal agrotechnical terms for each region. During the growing season, the condition of crops was monitored, weeds, pests and diseases were controlled. Harvesting was carried out by a combine harvester ‘Yenisei-1200’, after which the yield of each crop on each variant of tillage was determined. The costs of technological operations were also taken into account, namely the consumption of fuel, seeds, fertilisers, plant protection products, depreciation of equipment and wages of mechanics.

The conducted research has shown that minimum tillage has a positive effect on the yield of grain crops in comparison with traditional ploughing. The average yield of winter wheat at minimum tillage was 48 c/ha, which is 7-10% higher than in the variant with traditional ploughing. Similar results were obtained for spring barley, whose yield at minimum tillage was 42 c/ha, while at traditional tillage - 39 c/ha. The results obtained during the experiment agree with the data presented in the article [13], where it was noted that cereal crops are more responsive to minimum tillage. Oat yields also increased by 5-7% when minimum tillage was used, reaching 35 kg/ha compared to 32 kg/ha with conventional tillage. Under no-tillage, yields decreased by 8-10% compared to minimum tillage, but were still at the level of conventional tillage when all necessary agronomic measures were observed. However, it is worth noting that weather conditions, which varied in different years of the experiment, had a significant impact on yields. In favourable years, the difference between the treatment options was less pronounced.

The analysis of economic indicators showed that the use of minimum tillage contributes to a significant reduction in fuel and fuel and lubricants costs, as well as labour costs for mechanics.

Costs for soil tillage at minimum technology were 25-30% lower than at traditional ploughing. However, at minimum tillage there was an increase in herbicide costs, which is due to higher weediness of fields.

At the same time, the overall economic indicators with minimum tillage were higher than with conventional ploughing. Thus, the use of minimum tillage is not only ecologically expedient, but also economically favourable.

In case of zero tillage, the costs of fuel and lubricants were even lower, but additional costs were required to purchase a special seeder and use more expensive herbicides for weed control.In other plots, a minimum tillage system was used, where ploughing was excluded and tillage was limited to spring loosening with a KPS-4

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cultivator to a depth of 5-7 cm and harrowing with a BDT-3 disc harrow to a depth of 5-6 cm.In plots with zero tillage, the soil was not mechanically disturbed before sowing.Sowing in all variants was carried out with a grain seeder SZ-3.6. Winter wheat, spring barley and oats were used as experimental crops.Sowing was carried out in optimal agrotechnical terms for each region.

This is due to the fact that at minimum tillage the natural soil structure is preserved, soil aggregates and pores are not destroyed, which contributes to the improvement of water-air regime.

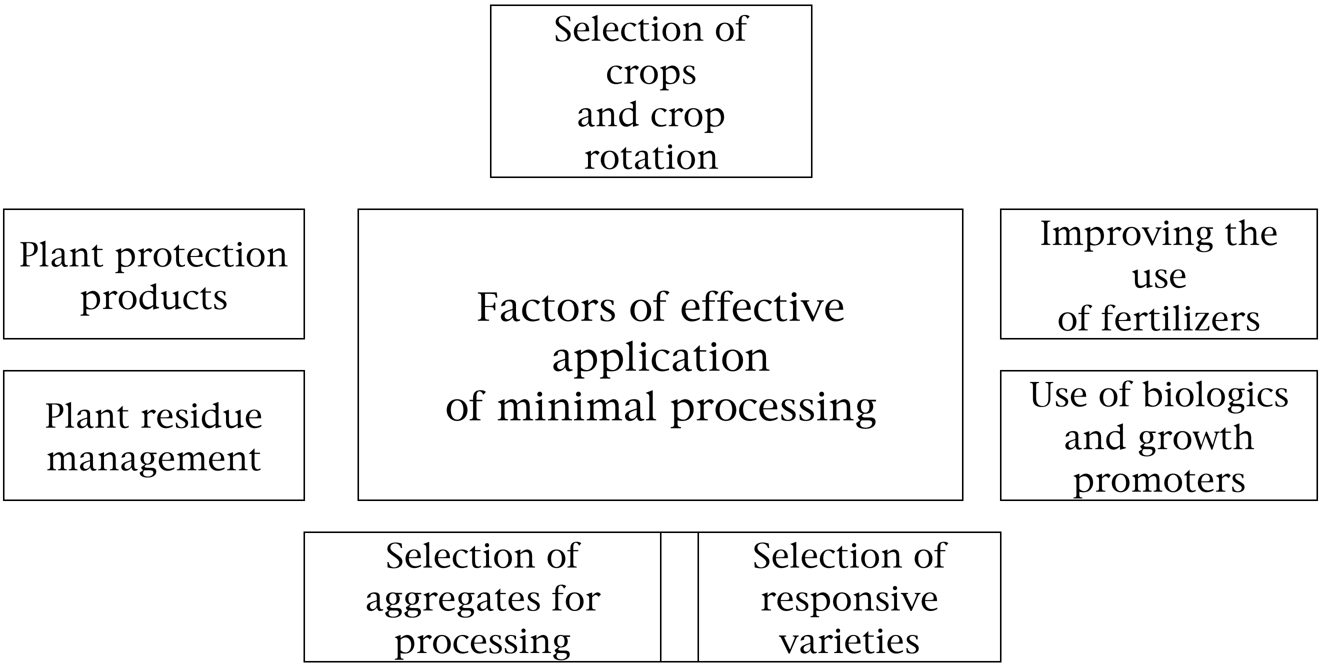

Figure 1. The level of provision with production of the main types of agricultural products in the Russian Federation

In addition, the plots with minimum tillage showed an increase in the number of earthworms, which indicates an improvement in the biological activity of the soil. Thus, on one square metre of soil under conventional ploughing the number of earthworms averaged 8 pieces, and on the variants with minimum tillage - 16 pieces. At zero tillage the number of earthworms was also higher than at traditional ploughing, but inferior to minimum tillage. There was also an increase in the humus content of the soil by 0.15-0.2 % compared to traditional tillage. These changes have a positive effect on soil fertility and contribute to more efficient assimilation of nutrients by plants. Thus, the obtained data indicate that minimum tillage is not only an effective way to increase the yield of grain crops, but also contributes to improving the ecological state of the soil, which makes this technology sustainable and promising in the long term. In the context of the need to reduce the negative impact of the agricultural sector on the environment, a comprehensive study of organic farming is required [14, 15].

Ultimately, the economic feasibility of introducing minimum and no-tillage should be assessed taking into account specific soil and climatic conditions and farm peculiarities [16].

According to Table 1, it was established that the choice of tillage system should be based on specific soil-climatic conditions and the level of production intensification. As shown in Figure 1, effective application of minimum tillage requires a comprehensive approach, including selection of crops and crop rotations, improvement of fertiliser application methods, use of biopreparations and growth stimulants, selection of aggregates for tillage and responsive varieties.

Table 1. Classification of tillage systems

System	Subsystems
Mouldboard	Miscellaneous Depth Minimal
Mulching	Deep
Combined	Multidepth Minimal
Zero	
Ridge-and-row	

The results obtained during the research agree with the conclusions presented in scientific publications on this subject. Minimisation of tillage improves soil structure, increases organic matter content and biological activity of soil. These effects have a positive impact on soil fertility and resistance of agro-ecosystems to unfavourable environmental factors. The economic efficiency of different types of tillage was also analysed. It was found out that the economic effect from the use of minimum tillage is achieved by reducing the cost of fuel and lubricants. It was confirmed that when switching to minimum tillage, careful weed control and adjustment of plant nutrition are necessary.

4 Conclusion

As a result of the conducted research the evidence of feasibility of introducing resource-saving tillage technologies in the cultivation of grain crops was obtained. Minimum tillage provides not only stable, but often higher grain yields compared to traditional ploughing. Thus, the yield of winter wheat at minimum tillage on average by 7-10% exceeded the yield at traditional tillage, and the yield of spring barley and oats was higher by 5-7%. At the same time, it should be noted that no-tillage in compliance with agronomic requirements provides yields at the level of traditional tillage, but requires a more careful approach to plant protection and may not always be economically justified. In the context of data on the influence of mountain factors on soil salt composition [17], it is important to take into account regional conditions when choosing tillage technologies.

In addition, an important finding is the significant reduction in fuel and fuel and lubricant costs when switching to minimum tillage, which makes it more economically favourable compared to conventional ploughing. The costs of tillage were reduced by 25-30%. Improved agrophysical soil properties such as increased porosity, water permeability and organic matter content are also important benefits of minimum tillage. Minimum tillage contributes to the increase of soil biological activity, which positively affects its fertility and resistance to unfavourable factors. Thus, the introduction of minimum tillage is a promising direction in the development of sustainable agriculture, allowing to achieve both economic and environmental benefits. The results obtained confirm the need for further development and dissemination of resource-saving technologies in the agricultural sector, which is an important step towards ensuring food security and conservation of natural resources. It is important to emphasise the need to use methods to assess the impact of tillage on ecology and soil cover [18]. In conclusion, the choice of a particular tillage system should be based on a comprehensive analysis of agro-ecological conditions, economic factors and farm peculiarities, taking into account the need to ensure a balance between economic efficiency and environmental sustainability of agrarian systems.

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