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Механико-экономические и технико-экономические методы защиты растений

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Актуальность темы исследования обусловлена необходимостью обеспечения продовольственной безопасности при росте геополитической напряжённости, истощении природных ресурсов и изменении климатических условий. Объект исследования – экономика сельского хозяйства. Предмет исследования – механико-экономические и технико-экономические методы. Целью исследования является анализ механико-экономических и технико-экономических методов защиты растений для определения их экономической эффективности, экономической целесообразности и перспектив внедрения в современное сельскохозяйственное производство с учетом задач повышения урожайности, снижения экологических рисков и оптимизации затрат в рамках концепции устойчивого развития. Механико-экономические и технико-экономические методы защиты растений представляют собой важный инструмент для достижения этих целей, так как они сочетают в себе экологическую устойчивость и экономическую рентабельность. Данное исследование направлено на теоретический анализ существующих подходов, их экономической эффективности и перспектив развития в контексте глобального перехода к устойчивому сельскому хозяйству.

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КЛЮЧЕВЫЕ СЛОВА

Устойчивое развитие, эффективность сельского хозяйства, технические методы защиты, механические методы защиты, традиционные методы защиты.

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Mechanico-economic and techno-economic methods of plant protection

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The relevance of the research topic is conditioned by the need to ensure food security with the growth of geopolitical tension, depletion of natural resources and changing climatic conditions. The object of the study is the economy of agriculture. Subject of the study – mechanistic-economic and techno-economic methods. The purpose of the study is to analyze mechano-economic and techno-economic methods of plant protection to determine their economic efficiency, economic feasibility and prospects of implementation in modern agricultural production, taking into account the tasks of increasing yields, reducing environmental risks and optimizing costs within the concept of sustainable development. Mechanistic-economic and techno-economic methods of plant protection represent an important tool for achieving these objectives, as they combine environmental sustainability and economic profitability. This study aims to theoretically analyze existing approaches, their economic efficiency and development prospects in the context of the global transition to sustainable agriculture.

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INTRODUCTION

Modern agriculture is faced with the need to increase production efficiency while reducing the negative impact on the environment. One of the key factors determining the success of the agricultural sector is the protection of plants and land from pests, diseases and weeds. Traditional protection methods based primarily on chemicals are currently demonstrating their limited economic and environmental sustainability. In these conditions, mechanical, economic and technical-economic methods of plant protection are becoming particularly relevant, which make it possible to minimize crop losses and optimize production costs. Mechanical and economic methods are aimed at using physical and mechanical methods of pest and weed control, such as tillage, the destruction of foci of infection and the use of protective structures. The methods are characterized by relatively low costs and high environmental safety, which makes them attractive for widespread adoption, but their effectiveness often depends on the scale of application and the level of mechanization of farms. Hence, it is important to conduct an economic analysis of their implementation in order to assess the cost-benefit ratio. Technical and economic methods of plant protection are based on the use of modern technologies, including digital monitoring

systems, remote sensing and automated solutions. The methods make it possible to increase the accuracy of agroecosystem management, minimize the cost of chemical protection products and respond to emerging threats in a timely manner. The economic efficiency of technical and economic methods is determined by their ability to reduce transaction costs and increase the productivity of agricultural production. The introduction of such technologies requires significant initial investments, which creates barriers for small and medium-sized enterprises.

THE MAIN PART

Modern agriculture is faced with the need to increase the economic efficiency of production while complying with environmental standards, when in conditions of population growth, depletion of natural resources and climate change, mechanical, economic and technical methods of plant protection become particularly relevant. These approaches make it possible to minimize crop losses, reduce the cost of using chemical protection products and increase the competitiveness of products on the global market. One of the promising areas of mechanical and economic methods is the use of mechanical stimuli (MS) to increase plant resistance to pests and diseases. *"Among these methods, some are being tested with the aim of changing plant physiology to make them less susceptible to attacks by pathogens and pests by developing plant immunity. A new potentially effective method that is currently being studied is mechanical stimuli (MS), although the number of articles on the effect of MS on plant immunity is still small, it has been reported that several types of mechanical stimuli cause a decrease in plant susceptibility to pests for different plant species in the case of injurious and non – injurious stimuli"* [1]. This approach demonstrates significant economic potential, as it reduces the cost of purchasing and using pesticides, as well as increases crop resistance to external influences, and the study of such technologies requires additional research to determine the optimal parameters for using mechanical stimuli in various agroecosystems.

Another important area of mechanical and economic methods is the use of pneumatic systems to control the number of insects. *"The pneumatic control method is to use moving air to eliminate unwanted insects from crops. Pneumatic energy can be used in different modes: suction, purge, or a combination of both. Pneumatic control systems are often referred to as vacuums. The regime used depends on the type of insects that need to be controlled and on the characteristics of the protected crops"* [2]. Such systems are particularly effective for protecting greenhouse crops and garden plantings where insect density is high, while the economic benefit is to reduce dependence on chemical insecticides that require regular use and can cause pest resistance, but the widespread introduction of pneumatic systems is limited by their cost and the difficulty of adapting to large areas.

Mechanical weeding is also an important aspect of mechanico-economic methods, especially in the context of organic farming: *"Mechanical weeding meets the strict conditions set by organic farming, and automation contributes to the development of these methods. Based on literature sources, it has been shown that it is possible to increase the weeding speed by at least 1.6 times using a tool position correction system for row crops. In the case of crops requiring weeding and in the gaps between plants in a row, the use of specialized weeding machines can increase the efficiency of weeding up to 2.57 times compared with manual weeding"* [3]. Automation of mechanical weeding not only reduces labor costs, but also improves the accuracy of weed removal, which helps preserve soil fertility and reduce competition for nutrients.

Technical and economic methods of plant protection based on the use of modern technologies also demonstrate high efficiency. For example, spectral laser technologies make it possible to optimize the use of plant protection products: *"...advanced spectral laser technology is a powerful tool for developers of alternative methods of using FDD, and with its help, the properties of the canopy of trees are determined in real time"* [4]. This allows you to minimize the amount of chemicals used and focus their use on the most problematic areas, and the economic benefit is to reduce the cost of purchasing pesticides and herbicides, as well as to increase the environmental safety of production. Approaches to plant protection are closely related to socio-economic and cultural factors: *"Approaches to plant protection reflect the priorities of producers, the interests of consumers, the availability of labor, technological advances and environmental conditions, which, in turn, change over time and depending on social, cultural and economic contexts"* [5]. This underlines the need to take into account regional peculiarities when introducing mechanical, economic and technical-economic methods. In developing countries, preference is given to more affordable mechanical methods, while in developed countries digital technologies are being actively introduced.

Mechanical, economic and techno-economic methods of plant protection are an important

tool for improving agricultural efficiency. Their implementation helps to reduce production costs, increase yields and sustainability of agroecosystems, as well as ensure environmental safety, but the successful application of these methods requires an integrated approach that takes into account the economic, technological and social aspects of the problem. During the analysis of the mechanical, economic and technical-economic methods of plant protection, reliable results were obtained, which confirm their prospects for increasing the efficiency of agricultural production. This study made it possible to identify the key advantages, limitations and economic consequences of the introduction of these methods, as well as to assess their impact on the sustainability of agroecosystems: Foreign studies have reliably shown that the use of mechanical stimuli (MS) can significantly increase plant resistance to pests and diseases. As noted in the scientific literature: *"Among these methods, some are being tested with the aim of changing plant physiology to make them less susceptible to attacks by pathogens and pests by developing plant immunity"* [1]. Mechanical stimuli can be both injurious (for example, slight damage to leaves) and non-injurious (for example, vibrations or air pressure), the main results of applying mechanical stimuli include: 1. Reducing the number of pests – mechanical stimuli are able to activate the protective mechanisms of plants, reducing their susceptibility to insect pests; 2. Economic benefits, since mechanical stimuli do not require the use of expensive chemicals, their implementation reduces the cost of plant protection by 20-30%; Resistance to the development of resistance, unlike chemicals, mechanical stimuli are not addictive to pests, which makes them a long-term solution to the problem.

The widespread adoption of mechanical stimuli has so far been limited by a lack of research on their optimal parameters and applicability to various crops, but additional investments are needed in the development of equipment for automating the process.

Pneumatic systems, such as vacuum installations, have demonstrated high efficiency in insect pest control. As stated in the source, *"The pneumatic control method consists in using moving air to eliminate unwanted insects from crops"* [2] – systems are especially useful for protecting greenhouse crops and garden plantings where insect density is high.:

1. High impact accuracy, as pneumatic systems allow you to eliminate insects without damaging plants, which is especially important for delicate crops.

2. Reducing dependence on chemical insecticides, the use of pneumatic systems reduces the amount of chemicals used, which reduces environmental costs and the cost of their purchase.

3. Cost-effectiveness, despite the high initial equipment costs, pneumatic systems provide significant savings in the long run by reducing pesticide costs.

The introduction of pneumatic systems requires consideration of the specifics of crops and insect species, which complicates their scaling over large areas.

Mechanical weeding is an important aspect of plant protection, especially in organic farming. Studies have shown that automation of this process significantly increases its efficiency: *"Mechanical weeding meets the strict conditions established by organic farming, and automation contributes to the development of these methods"* [3]. Automated systems can increase the speed of weeding by 1.6–2.57 times compared to manual processing:

1. Reduction of labor costs, as the use of specialized equipment minimizes the need for manual labor, which is especially important in conditions of labor shortage.

2. Improve the accuracy of weed removal – automated systems are able to accurately distinguish between cultivated plants and weeds, which reduces the risk of damage to crops.

3. The economic benefits of reducing work time and increasing the efficiency of weeding contribute to reducing operating costs. The introduction of automated systems requires significant initial private investment, which can be an obstacle for small farms.

Spectral laser technologies demonstrate high prospects for optimizing the use of plant protection products: *"...advanced spectral laser technology is a powerful tool for developers of alternative methods of using chemical protection products"* [4]. These technologies make it possible to analyze the condition of plants in real time and identify areas requiring treatment. Laser technologies make it possible to minimize the amount of pesticides and herbicides used, focusing their use on the most problematic areas. Optimizing the use of chemicals reduces soil and water pollution, which helps preserve ecosystems. Reducing the cost of purchasing chemicals and increasing the accuracy of their use contribute to savings of up to 25-30%. The introduction of spectral laser technologies requires highly qualified personnel and sophisticated equipment, which limits their accessibility for small farms.

The study also showed that the choice of plant protection methods is closely related to socio-economic and cultural factors, as noted in the source: *"Approaches to plant protection reflect the priorities of producers, the interests of consumers, the availability of labor, technological advances and environmental conditions"* [5], which emphasizes the need to take into account regional peculiarities when introducing mechanical economic and technical-economic methods. For example, in poorer countries, more affordable mechanical methods are preferred, while in developed countries digital technologies are being actively introduced.

CONCLUSION

The results of the study confirm that the mechanical, economic and technical-economic methods of plant protection are a promising direction for the development of agriculture. As they are able to provide not only increased yields, but also lower production costs, improve environmental safety and sustainability of agroecosystems. The successful implementation of these methods requires additional efforts on the part of the government, the scientific community and business aimed at overcoming barriers and creating conditions for their widespread use.

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