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THE ECOLOGICAL AND ECONOMIC ASPECTS OF THE USE OF PLANT PROTECTION PRODUCTS

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Annotation: This article provides a detailed analysis of the ecological and economic impact of plant protection products, particularly pesticides and biological agents. The research explores how effective use of pesticides can increase crop yield and economic benefits, while also ensuring the long-term ecological safety provided by biological agents. The use of biological agents in combination with pesticides and their role in maintaining ecological balance is particularly emphasized. The article also highlights the need to develop innovative approaches to reduce the ecological impact of pesticides and increase the use of biological agents.

Keywords: pesticides, biological agents, ecological safety, economic efficiency, plant protection, innovative technologies, agricultural economy.

Introduction. Plant protection plays a crucial role in the effective and sustainable development of agriculture. Among the widely used tools for plant protection are pesticides and biological control agents. Pesticides are used to combat plant pests, diseases, and weeds, while biological agents help protect plants without causing harm to the environment. At the same time, the ecological and economic impacts of using these tools, as well as their effectiveness, are vital in ensuring the sustainability of agricultural systems.

According to data from the Food and Agriculture Organization (FAO) of the United Nations, approximately 20-40% of agricultural products are lost annually worldwide due to plant pests and diseases. This leads to a decrease in agricultural production, food security challenges, and economic losses. Therefore, the role of plant protection tools remains critical, and ongoing research in this field highlights its relevance.

Today, there are extensive scientific studies on the role of pesticides and biological agents in plant protection, focusing on their effectiveness, ecological safety, economic impact, and scope. While pesticides are essential for protecting plants from pests, their excessive or improper use can harm soil quality, water resources, and biodiversity. Hence, proper management of pesticides and biological agents, along with their enhancement through modern innovative technologies, is necessary.

The relationship between the ecological and economic aspects of plant protection tools plays a key role in ensuring sustainability in agriculture. A comprehensive understanding of the ecological and economic advantages of using pesticides and biological agents is essential for establishing a sustainable agricultural system. This article analyzes the economic and ecological effectiveness of pesticides and biological agents, their role in agricultural development, and their impact on ecological security.

Through the analyses and statistical data presented in this article, innovative approaches for more effective use of pesticides and biological agents in plant protection are proposed. These approaches, in turn, will help ensure that agricultural products are of higher quality and more environmentally safe.

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Literature Review. The role of plant protection products, especially pesticides and biological agents, has been extensively studied by both domestic and foreign researchers, emphasizing their ecological and economic implications. This section reviews the work of several scholars in the field to highlight the importance of using these tools in agriculture while maintaining a balance between productivity and environmental sustainability.

One of the key contributions to the understanding of pesticide use comes from Shukurov [1], who examined the economic effectiveness of pest control strategies in Central Asia. His study emphasized the importance of integrated pest management (IPM) to reduce the overreliance on chemical pesticides and improve both productivity and environmental outcomes. Jumaev [2]), on the other hand, focused on the ecological risks associated with pesticide use in Uzbekistan, pointing out the significant challenges posed by pesticide residue in the soil and water, as well as its effects on biodiversity.

In the international context, Smith and Roberts [3] explored the economic impact of pesticides on crop yields in developed countries, providing evidence that while pesticides contribute to higher yields and agricultural productivity, they also incur significant external costs related to environmental damage and public health issues. Their findings support the view that long-term sustainability in agriculture requires a careful balance between pesticide use and environmental conservation.

Zhang et al. [4] studied biological pest control as an alternative to chemical pesticides. Their research focused on the economic benefits of using natural predators and biopesticides in pest management, showing that biological agents, although often more expensive upfront, lead to long-term economic savings by reducing environmental cleanup costs and improving biodiversity.

In terms of innovation, Nikitin and Tarasov [5] examined recent advancements in biotechnological approaches to plant protection. They identified several innovative biological products that can effectively manage pests without causing harm to the environment, thus contributing to the sustainability of agricultural systems.

The aforementioned studies illustrate the complex relationship between the economic and ecological impacts of plant protection products. They all emphasize that while pesticides and biological agents are indispensable in modern agriculture, their use must be carefully managed to prevent negative environmental and health consequences. Innovative strategies such as integrated pest management (IPM), the development of eco-friendly biological agents, and the adoption of sustainable agricultural practices are seen as essential for ensuring both ecological safety and economic efficiency in plant protection.

In conclusion, the literature strongly supports the need for a balanced approach to using pesticides and biological agents in agriculture. It is clear that these tools play an essential role in ensuring food security and increasing agricultural productivity. However, their use must be regulated and combined with innovative, eco-friendly practices to mitigate the ecological risks associated with their application. The shift toward more sustainable agricultural systems, incorporating biological control methods and IPM, is crucial for achieving long-term agricultural sustainability.

Research Methodology: This study focuses on analyzing the economic and ecological effectiveness of pesticides and biological agents in agriculture. The primary methodology of the study is based on a review of literature and existing analyses. The following approaches are employed in this process: At the beginning of the research, scientific works and practical studies related to pesticides and biological agents are analyzed. Through this method, information on the latest scientific developments, technologies, and the economic and

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ecological impacts associated with them is gathered. Based on the literature, the effectiveness, economic and ecological impact of pesticides and biological agents are analyzed. These analyses allow the evaluation of the practical outcomes of plant protection tools and their contributions to agriculture.

Analysis and Results. This study analyzed the economic effectiveness and environmental impact of the use of pesticides and biological agents in agriculture, leading to the following results.

1. **Economic Effectiveness of Pesticides and Biological Agents:** The use of pesticides and biological agents has a significant role in increasing productivity in agriculture. Research findings confirm that pesticides are effective in combating plant pests and diseases. Specifically, when applied on a large scale, pesticides resulted in an increase in productivity by 20-30%. Biological agents, while yielding environmentally positive outcomes, generally demonstrated lower efficacy compared to pesticides in certain conditions. Though biological agents are economically less effective than pesticides in the short term, they contribute significantly to long-term environmental sustainability.
2. **Environmental Impact:** The environmental impact of pesticides is a widely debated issue. Research has shown that improper use of pesticides negatively affects soil and water resources, causing soil contamination, water pollution, and harmful impacts on flora and fauna. On the other hand, biological agents have shown positive environmental results. However, their effectiveness in combating pests is sometimes less immediate compared to pesticides, and their impact may be limited in certain situations.
3. **Role of Innovative Technologies:** Innovative technologies play a vital role in enhancing the efficiency of both pesticides and biological agents. New-generation pesticides are being developed that are more selective and can be used in smaller quantities while being harmless to crops. In biological agents, advancements in biotechnology offer ways to further improve the selectivity and effectiveness of microorganisms. Additionally, the combination of pesticides and biological agents in integrated pest management strategies contributes to improving both ecological safety and productivity.
4. **Practical Application of the Analysis Results in Agriculture:** The results indicate that the proper use of pesticides and biological agents enhances the stability and productivity of agricultural yields. In countries where there is a strong focus on the efficient use of pesticides and biological agents, the quantity and quality of agricultural products have significantly improved. For example, in Russia and China, the proper use of pesticides and biological agents has led to increased yields while maintaining ecological security.

The overall findings from the study show that pesticides and biological agents are effective tools in combating pests in agriculture. However, they must be used carefully with consideration for ecological safety. Biological agents offer promising environmental benefits, but to enhance their effectiveness, there is a need to develop innovative technologies. An optimal strategy for using pesticides and biological agents can lead to increased productivity, economic benefits, and the preservation of ecological security.

Conclusion and Recommendations. The use of pesticides and biological agents in agriculture has a significant economic and environmental impact. Research findings indicate that while pesticides are essential for controlling plant pests and diseases, they must be used judiciously to minimize their negative effects on the environment. Pesticides have proven to be highly effective in increasing agricultural productivity, particularly in the short term. However, their improper or excessive use can lead to soil and water contamination, which poses long-term environmental risks.

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On the other hand, biological agents, although slower to show immediate results, present a more sustainable and eco-friendly alternative. Biological agents, such as beneficial microorganisms and natural predators, offer significant potential for integrated pest management (IPM) systems, which help reduce the reliance on chemical pesticides. In the long run, biological agents contribute to ecological balance, promoting sustainable agricultural practices.

The role of innovative technologies in improving both pesticide and biological agent effectiveness cannot be overstated. Advancements in biotechnology have led to the development of more selective and environmentally friendly pest control methods. Furthermore, integrated pest management systems that combine both pesticides and biological agents show promising results in achieving the desired balance between productivity and ecological safety.

Recommendations:

1. **Promote Integrated Pest Management (IPM):** There is a need for a more widespread adoption of Integrated Pest Management (IPM) practices that combine the use of both chemical and biological agents. This approach ensures that pest control is effective while minimizing environmental impact. IPM strategies should be developed with local agricultural conditions in mind, and farmers should be trained in their proper implementation.
2. **Develop and Use Eco-friendly Pesticides:** Research and development of eco-friendly pesticides should be prioritized. This includes developing more selective pesticides that target only harmful pests and minimize collateral damage to non-target species. Additionally, the use of biopesticides, derived from natural sources, can be encouraged to reduce environmental harm.
3. **Invest in Biotechnology for Biological Control:** Continued investment in biotechnology is essential to improving the effectiveness of biological control agents. The development of genetically engineered microorganisms or natural predators with enhanced abilities to combat pests should be explored. This can increase the success rate of biological agents and make them more competitive with traditional pesticides.
4. **Regulation and Monitoring:** Governments should implement and enforce stricter regulations on the use of pesticides to ensure their safe application. Regular monitoring of pesticide residues in soil, water, and crops is necessary to avoid environmental contamination. This could also include creating databases on pesticide usage and its impacts on ecosystems.
5. **Farmer Education and Awareness:** Training programs for farmers on the proper application of both pesticides and biological agents are crucial. These programs should focus on the benefits of IPM and sustainable farming practices, helping farmers make informed decisions that benefit both their yields and the environment. Furthermore, providing financial incentives or subsidies for using eco-friendly pest control methods could encourage wider adoption.

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