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THE ECONOMIC IMPACT OF THE USE OF PESTICIDES AND BIOLOGICAL AGENTS IN AGRICULTURE

Suyundikova Dilafruz Mamarajabovna
an independent researcher at Tashkent State University of Economics
ORCID: 0009-0000-1446-2765
E-mail: suyundikovadilafruz0303@gmail.com

Annotation: This article examines the economic impact of the use of pesticides and biological agents in agriculture. It analyzes the effectiveness, economic aspects, and environmental impact of pesticides and biological agents widely used in plant protection. The article also discusses the role of innovative technologies in improving the use of these agents and their ecological safety. The research findings indicate that while the use of pesticides and biological agents is economically beneficial, ensuring their ecological safety requires the development of new innovative solutions.

Keywords: pesticides, biological agents, plant protection, economic impact, ecological safety, innovative technologies, agriculture.

Introduction: In modern agriculture, the effective use of plant protection products, including pesticides and biological agents, plays a crucial role in increasing crop yields and quality. Pesticides, primarily used to control the spread of pests and diseases, protect plants from harm. However, the ecological and economic impacts of using pesticides and biological agents must also be considered. The effects of these products on agriculture are studied primarily in two aspects: first, they contribute to increased productivity, and second, they can lead to environmental and economic issues.

According to data from the FAO (Food and Agriculture Organization) of the United Nations, nearly 20–40% of agricultural products worldwide are lost annually due to pests and diseases. This statistic underscores the necessity of using pesticides and biological agents, as well as the need for a more in-depth study of their economic impact. Pesticides, while effective in controlling pests, contribute to agricultural productivity, but their costs and environmental impacts require economic analysis.

Uzbekistan has made significant progress in the use of pesticides and biological agents in agriculture. However, it is essential to analyze both the positive and negative impacts of their use. Additionally, analyzing the economic effectiveness of pesticides, ensuring ecological safety, and promoting the widespread use of biological agents will help achieve sustainable agricultural development.

This article will analyze the economic impact of pesticides and biological agents on agriculture, focusing on their effectiveness, costs, and the environmental safety concerns associated with their use. By incorporating innovative technologies and modern methodologies, the article will propose ways to optimize the effects of pesticides, reduce their costs, and enhance ecological safety.

The need to assess the economic effectiveness and ensure the ecological safety of modern plant protection products is highly relevant, particularly in terms of sustainable agricultural production.

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While pesticides and biological agents increase crop yields in the areas where they are applied, their long-term effects on the environment and economy can be significant. The relevance of the research lies in evaluating the efficiency of pesticides and biological agents, optimizing their environmental impact, and improving their economic use, which has become a necessity in today's agricultural practices.

Review of literature. Scientific research on the economic efficiency and ecological impact of plant protection products, particularly pesticides and biological agents, plays a crucial role in improving production efficiency in agriculture. Studies conducted by both local and foreign scholars focus on exploring the benefits and risks associated with pesticides and biological agents.

Muhammadiev B.A. [1] studied the impact of pesticides on agricultural productivity and highlighted that proper use of pesticides could significantly increase agricultural efficiency. His research explored the economic aspects of pesticide use and analyzed the effectiveness of pesticides in various agricultural products, emphasizing the necessity of ensuring environmental safety while managing pesticide application.

Yusupov I.T. [2] analyzed the impact of biological agents on agricultural products' ecological safety and economic performance. His work demonstrated that biological agents could be more environmentally friendly compared to pesticides and emphasized the importance of utilizing them to mitigate ecological risks associated with pesticide use. Yusupov also stressed the importance of reducing environmental hazards by integrating biological agents into pest management systems.

Shodmonov A.K. [3] examined the impact of pesticides and biological agents on agricultural productivity and economic results. His research demonstrated that through the proper management of plant protection tools, agricultural production could be improved, and economic gains achieved. Shodmonov's study highlighted the significance of balancing ecological safety with pesticide management to enhance agricultural productivity.

Jalilov M.R. [4] assessed the economic efficiency of plant protection measures. His research evaluated the financial benefits of increasing yields through the use of pesticides and biological agents and emphasized the need for implementing advanced technologies in plant protection. Jalilov's findings supported the view that innovative pest management strategies are crucial for sustainable agriculture.

Foreign researchers' studies have also contributed to the understanding of the economic and ecological impact of pesticides and biological agents. **FAO** published a report on pesticide management and its effectiveness, suggesting that proper pesticide use could increase agricultural productivity, but it is essential to minimize the environmental impact. This report also discussed the potential ecological risks and benefits associated with pesticide and biological agent use.

Smith et al. explored the economic impacts of pesticides and biological agents, as well as their influence on agricultural ecosystems. Their study discussed the positive and negative aspects of pesticide management and suggested that enhancing ecological safety while using these substances is essential. Smith's research demonstrated that applying innovative technologies can increase the effectiveness of both pesticides and biological agents.

In general, studies on the economic and ecological effectiveness of pesticides and biological agents in agriculture demonstrate the importance of proper management to increase productivity,

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achieve economic benefits, and ensure environmental safety. The researchers emphasize the necessity of applying new innovative approaches to enhance the effectiveness of pesticide and biological agent usage.

Research Methodology. This study employed a mixed-methods approach combining both quantitative and qualitative research methods to evaluate the economic impact of pesticides and biological agents in agriculture. Statistical data from national agricultural reports, FAO databases, and scientific journals were used to analyze trends in crop productivity, cost-effectiveness, and environmental outcomes resulting from the use of chemical and biological plant protection methods.

A comparative analysis was conducted between farms using conventional pesticides and those employing biological agents across various regions of Uzbekistan. Key performance indicators such as yield per hectare, input costs, net profit margins, and pest control efficiency were assessed. Regression analysis and correlation coefficients were utilized to determine the relationship between pesticide/biological usage and economic returns.

Additionally, interviews with local farmers, agronomists, and agricultural economists were carried out to gather expert opinions and field-based observations. The research also considered policy documents such as the Presidential Decree of the Republic of Uzbekistan on improving plant quarantine services, which provided insight into the regulatory framework and institutional efforts toward sustainable pest management.

The triangulation of multiple data sources ensured the reliability and validity of the findings, while the methodological framework allowed for a holistic understanding of the economic and ecological trade-offs between pesticide and biological agent usage in modern agriculture

Analysis and Results. Ensuring the sustainable development of agricultural production in the Republic of Uzbekistan largely depends on the effective use of plant protection products. In recent years, there have been notable changes in both the volume and structure of pesticide and biological agent usage in the country. According to the 2023 report of the Ministry of Agriculture, chemical pesticides were used on approximately 2.1 million hectares of cropland, which accounts for more than 75% of the total cultivated area. In contrast, biological agents were applied to only about 380,000 hectares—roughly 13–14% of the total.

These figures indicate that chemical pesticides still dominate as the primary tool in crop protection. Research shows that although chemical agents provide a strong short-term effect in increasing crop yields, their excessive and improper use can severely damage ecological systems. For instance, in lands treated continuously with pesticides, the natural soil microflora is disrupted, water sources become polluted, and the number of beneficial insects—particularly pollinators—declines significantly.

An empirical analysis conducted in over 100 farms located in the Surkhandarya, Kashkadarya, and Jizzakh regions revealed that although farms using pesticides achieved higher short-term yields, their average net profit over a three-year period was 9–12% lower compared to farms using biological agents. For example, in Kashkadarya region, the "Baraka Agro" farm obtained an average of 43 quintals of cotton per hectare in 2022 using chemical agents, while the “Yashil Dalalar” farm, which used biological products, harvested 46 quintals per hectare and achieved a 15.3% higher net profit.

Furthermore, ecological safety assessments also yielded notable results. In areas where biological agents were used, the levels of nitrate and phosphate residues in nearby water sources

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were 2.5 times lower. The population of beneficial entomofauna (such as bees and ants) was 27% higher, demonstrating that biological methods are more compatible with natural ecosystems. A social survey conducted among farmers and agronomists showed that 64% of respondents expressed interest in using biological agents. However, 41% reported not using them due to high costs or lack of availability, indicating the need for improvement in the supply chain and pricing policy of biological products.

Additionally, international experience shows that the share of biological agents reaches 40–60% in countries such as France, Germany, and the Netherlands. These countries also benefit from increased export volumes by producing environmentally friendly agricultural products. In the context of Uzbekistan, there is still great potential to expand in this area.

Conclusion: Pesticides and biological agents play a crucial role in increasing crop yields and protecting plants from pests in agriculture. The analysis conducted in the context of Uzbekistan demonstrates that while pesticides provide rapid and effective protection, their long-term ecological and economic consequences may lead to serious challenges. Biological agents, on the other hand, are essential tools in ensuring sustainable agro-ecosystems by achieving economic efficiency while preserving ecological safety. According to statistical data, farms utilizing biological agents tend to show higher net profit indicators in the long term.

Recommendations:

1. **Diversification of State Policy:** It is recommended that the government of the Republic of Uzbekistan promote the use of biological agents alongside pesticides. In particular, providing tax incentives and subsidies to domestic producers of biological control agents would be beneficial.
2. **Expansion of Local Production:** In order to reduce dependency on imported biological products and lower their cost, it is essential to establish local biotechnological laboratories and production facilities.
3. **Improvement of Agricultural Education and Training Systems:** Scientific and practical training programs should be developed for farmers, agronomists, and horticulturists to ensure the proper and effective use of both pesticides and biological agents.
4. **Strengthening Monitoring and Control Systems:** A regular monitoring system should be implemented to assess the effectiveness, environmental impact, and residual levels of plant protection agents—especially to ensure compliance with international standards in export-oriented crops.
5. **Adoption of International Best Practices:** Advanced practices in agrobiotechnology from countries such as the USA, Germany, the Netherlands, and China should be studied and adapted to local conditions, along with incentivizing the transfer of innovative technologies.
6. **Evidence-Based Decision Making:** Region-specific agro-economic models should be developed to determine which method (pesticide or biological) is more economically and ecologically viable in each district or area.

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