

ECONOSCITECH INTEGRATION

ISSUE
5

INTERNATIONAL SCIENTIFIC
ELECTRONIC JOURNAL



TASHKENT STATE
UNIVERSITY OF ECONOMICS



American University
of Technology

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ISSN: 3060-5075



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2026

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THE SCIENTIFIC-POPULAR
ELECTRONIC JOURNAL
"ECONOSCITECH-INTEGRATION"
HAS BEEN REGISTERED UNDER
THE NUMBER C-5669651 BY THE
AGENCY FOR INFORMATION AND
MASS COMMUNICATIONS (AOKA)
OF THE REPUBLIC OF UZBEKISTAN,
EFFECTIVE FROM OCTOBER 9, 2024.

In accordance with Resolution No. 384/6 dated April 10, 2026, issued by the Presidium of the Supreme Attestation Commission under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan, this journal is included in the list of recommended international scientific publications for publishing the primary research findings of doctoral dissertations in the field of Economic Sciences.

Partners: Tashkent State University of Economics / American University of Technology in Tashkent (AUT)

Electronic publication, Issue 5. 374 pages.
Approved for publication on May, 2026.

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EFFECTIVENESS OF USING BIOLOGICAL METHODS IN PLANT PROTECTION: STATISTICAL ANALYSIS OF DISTRIBUTION STRATEGY AND PRACTICAL IMPLEMENTATION DENSITY



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Annotation. This article presents a statistical analysis of the effectiveness of using biological agents in plant protection, with particular attention to discrepancies between the planned quantities and actual distribution of these agents across agricultural fields. The study examines the application of entomophagous biological products, such as Oltinko'z, Trichogramma, and Bracon, in wheat and cotton fields during the 2024 harvest season in the Republic of Uzbekistan. Differences between planned and actual implementation levels are identified based on such indicators as the number of biolaboratories, the number of farms, the quantity of biological products, and their distribution density across fields. The article also examines the ecological and economic benefits of biological protection measures and proposes statistical approaches for assessing their impact on crop productivity.

Keywords: biological protection, entomophages, bioproducts, Oltinko'z, Trichogramma, Bracon, plant protection, statistical analysis, planned and actual discrepancy, distribution density, ecological safety, biolaboratory, farming enterprise.

Аннотация. В данной статье представлен статистический анализ эффективности применения биологических средств защиты растений с особым акцентом на выявление расхождений между запланированными и фактическими объемами их распределения на сельскохозяйственных угодьях. Исследование посвящено применению энтомофагов — златоглазки (Oltinko'z), трихограммы (Trichogramma) и бракона (Bracon) — на посевах пшеницы и хлопчатника в период урожайного сезона 2024 года в Республике Узбекистан. Различия между плановыми и фактическими показателями внедрения определены на основе таких статистических индикаторов, как количество биолaborаторий, число фермерских хозяйств, объем биологической продукции и плотность её распределения на сельскохозяйственных площадях. Кроме того, в статье рассматриваются экологические и экономические преимущества биологических методов защиты растений, а также предлагаются статистические подходы к оценке их влияния на урожайность сельскохозяйственных культур.

Ключевые слова: биологическая защита растений, энтомофаги, биопрепараты, златоглазка (Oltinko'z), трихограмма, бракон, защита растений, статистический анализ, расхождение между плановыми и фактическими показателями, плотность распределения, экологическая безопасность, биолaborатория, фермерское хозяйство.

INTRODUCTION

Plant protection against harmful organisms plays a crucial role in ensuring sustainable agricultural development, increasing crop productivity, and protecting agro-ecosystems. Since the intensive use of traditional chemical agents may lead to both economic and ecological challenges, the importance of biological control methods has increased significantly. In this context, the use of biological agents, particularly natural entomophages such as Oltinko'z, Trichogramma, and Bracon, has become one of the key priorities of national agricultural policy, as these methods offer environmentally safe solutions for pest control.

Resolution No. PQ-4861 of the President of the Republic of Uzbekistan, dated October 13, 2020, defines specific measures to further improve the activities of the State Plant Quarantine Service. The resolution sets

clear tasks for the scientific modernization of the plant protection system, expanding the production of biological agents, and organizing their practical application in agricultural fields. It also emphasizes the need to improve the activities of biological laboratories, promote the effective use of entomophages against local pests, and strengthen mechanisms for state support of biological protection measures.

Nevertheless, statistical analyses of discrepancies between the planned and actual quantities of biological products distributed across agricultural fields, the reasons for these discrepancies, regional distribution density indicators, and the effectiveness of biological protection measures have not yet been sufficiently systematized. This makes the study of this topic scientifically and practically relevant.

This study examines the effectiveness of using biological agents in plant protection, the discrepancies between planned and actual implementation levels in their regional distribution, distribution density, and related statistical indicators. The analysis focuses on data for 2024, including the number of farms, the volume of biological products distributed to wheat and cotton fields, planned and actual area coverage in hectares, the quantity of products in millions of units, and percentage differences.

The results of the study are of practical importance for forming a sustainable and environmentally friendly plant protection system in Uzbekistan's agriculture, ensuring the efficient use of resources, evaluating and improving the activities of biological laboratories, and making scientifically grounded agronomic decisions.

LITERATURE REVIEW

In recent years, the use of biological agents that are both ecologically safe and economically efficient has become increasingly important in plant protection as an alternative to chemical agents. Biological control methods involving entomophages, such as *Oltinko'z*, *Trichogramma*, *Bracon*, and other beneficial organisms, are considered an important factor in maintaining the stability of agro-ecosystems and ensuring effective pest control.

Resolution No. PQ-4861 of the President of the Republic of Uzbekistan, dated October 13, 2020, defines measures aimed at improving the activities of the State Plant Quarantine Service, developing the network of biological laboratories, introducing modern technologies, and expanding the production and application of entomophages. Based on this document, a planned and systematic approach to the use of biological plant protection agents has been established in the country [1].

The scientific literature examines various aspects of the use of entomophages. In particular, Karimov B. K. studied their agro-biological foundations [2], Rustamova D. analyzed their impact on ecosystems [3], and Islomov A. examined their economic efficiency [4]. In addition, Yoqubov S. investigated the advantages and limitations of distribution mechanisms across regions [5]. International organizations, including FAO [6] and ICARDA [7], have also emphasized the role of biological control methods in ensuring sustainable agriculture.

The effective operation of biological laboratories largely depends on their material and technical base, the availability of qualified personnel, and their regional location. According to the research of A. Tursunov [8], these factors directly influence the production of biological products and their timely delivery to agricultural fields.

In local practice, insufficient attention has been paid to comparing the planned and actual distribution density of biological products and conducting statistical analysis of the factors influencing their effectiveness. This further emphasizes the scientific relevance and practical significance of the present research topic.

RESEARCH METHODOLOGY

This study examines the effectiveness of using biological agents in plant protection within the agricultural sector of the Republic of Uzbekistan on the basis of statistical methods. The main focus is placed on analyzing the planned distribution of biological agents, such as *Oltinko'z*, across agricultural fields in different regions and comparing these plans with their actual implementation in practice. Based on this approach, the performance of biological laboratories in the country and the level of their practical utilization were evaluated using specific statistical indicators.

In the course of the study, official statistical reports for 2024 provided by the Ministry of Agriculture and other relevant organizations were used as the main data source. Based on these reports, graphical analysis, percentage difference analysis, time series analysis, and comparative analysis by regional distribution were conducted.

The discrepancies between planned and actual indicators were recorded in terms of both percentage and quantitative differences, and separate statistical results were presented for each biological agent. In particular, an efficiency analysis was carried out based on the distribution density of biological products per hectare, measured in millions of units or kilograms, as well as their coverage rate across regions.

ANALYSIS AND RESULTS

In recent years, the modernization of the plant protection system in Uzbekistan's agriculture has accelerated significantly. In particular, in 2024, the widespread use of biological agents was observed in pest control and preventive protection measures. Biological products produced by biolaboratories in the country, including entomophages such as Oltinko'z, have strengthened the mechanism for protecting agricultural crops while reducing reliance on chemical agents.

This section provides a statistical analysis of the planned and actual distribution of biological products to wheat and cotton fields across regions and districts in 2024. The analysis covers distribution density, discrepancies between planned and actual implementation, and efficiency levels across different regions. The study is based on official statistical data obtained from the Ministry of Agriculture of the Republic of Uzbekistan and biological laboratories.

Through this analysis, the practical status of biological control methods across regions is identified, including the level of resource utilization, positive outcomes, and areas requiring further improvement. In addition, the study forms a scientific basis for making decisions based on sustainable, environmentally friendly, and economically viable approaches to plant protection (Table 1).

Table 1

Indicators of the Distribution of Oltinko'z Biological Products to Agricultural Fields by Biolaboratories for Pest Control and Preventive Measures¹

No.	Region	Number of Biolaboratories	Wheat Field Area, ha	Area Treated with Oltinko'z Biological Product, ha	Quantity of Oltinko'z Biological Product, million units
1	Republic of Karakalpakstan	69	63,000	62,930	62.9
2	Andijan	86	82,000	79,568	79.6
3	Bukhara	35	76,894	77,141	77.1
4	Jizzakh	40	105,000	72,269	72.3
5	Kashkadarya	70	140,000	139,107	139.1
6	Navoi	11	38,039	31,386	31.4
7	Namangan	25	68,000	102,479	102.5
8	Samarkand	32	77,123	77,133	77.1
9	Surkhandarya	65	89,324	114,535	114.5
10	Syrdarya	35	78,000	75,109	75.1
11	Tashkent	43	103,000	70,311	70.3
12	Fergana	43	94,770	92,451	92.5
13	Khorezm	85	33,200	66,400	66.4

The data presented in the table make it possible to conduct a comparative analysis of the planned and actual volumes of Oltinko'z biological products distributed to wheat fields across different regions. These indicators serve as an important statistical basis for evaluating the effectiveness of using biological agents in plant protection.

Within the framework of this research, it is proposed to apply several statistical methods to conduct an in-depth and systematic analysis of the data. These methods include the following:

1. Assessment of the effectiveness of distributing Oltinko'z biological products to crop fields by biolaboratories for pest control and preventive purposes through percentage analysis of the gap between planned and actual implementation. This method involves calculating actual performance as a percentage of the planned volume for each region. It makes it possible to evaluate the efficiency of biological product distribution and determine the extent to which the planned outcomes have been achieved (Table 2).

$$\text{Plan Fulfillment (\%)} = \frac{\text{Actual Volume Implemented (ha)}}{\text{Planned Volume (ha)}} * 100\%$$

¹ author's development

Table 2. Effectiveness of Distributing Oltinko'z Biological Products to Crop Fields by Biolaboratories for Pest Control and Preventive Measures²

No.	Region	Wheat Area, ha	Actually Covered Area, ha	Plan Fulfillment, %
1	Republic of Karakalpakstan	63,000	62,930	99.89
2	Andijan	82,000	79,568	97.00
3	Bukhara	76,894	77,141	100.30
4	Jizzakh	105,000	72,269	68.83
5	Kashkadarya	140,000	139,107	99.36
6	Navoi	38,039	31,386	82.52
7	Namangan	68,000	102,479	150.70
8	Samarkand	77,123	77,133	100.01
9	Surkhandarya	89,324	114,535	128.22
10	Syrdarya	78,000	75,109	96.29
11	Tashkent	103,000	70,311	68.26
12	Fergana	94,770	92,451	97.55
13	Khorezm	33,200	66,400	200.00

In 2024, the analysis of the application of the Oltinko'z biological agent to wheat fields across the Republic of Uzbekistan as part of pest control and preventive measures showed that, in many regions, the actual use of this product exceeded the planned targets. Overall, the application of the agent was planned for 1,048,350 hectares of wheat fields; however, in practice, it was applied to 1,060,819 hectares. As a result, the plan fulfillment rate reached 101.19%.

1. Regional Analysis of Plan Fulfillment. The regional analysis shows considerable variation in the implementation of the planned distribution of the Oltinko'z biological product. The highest level of plan fulfillment was recorded in Khorezm Region, where implementation reached 200.00%, indicating the most intensive application of biological control measures. Similarly, implementation exceeded the planned targets in Namangan Region (150.70%) and Surkhandarya Region (128.22%), suggesting either a greater need for biological protection due to higher pest pressure or a conservative estimation of the initial distribution plan (Figure 1).

In contrast, Jizzakh Region (68.83%) and Tashkent Region (68.26%) recorded the lowest plan fulfillment rates. These deviations may reflect differences in local implementation conditions, resource allocation, logistical capacity, or updated field requirements during the implementation period (Figure 1).

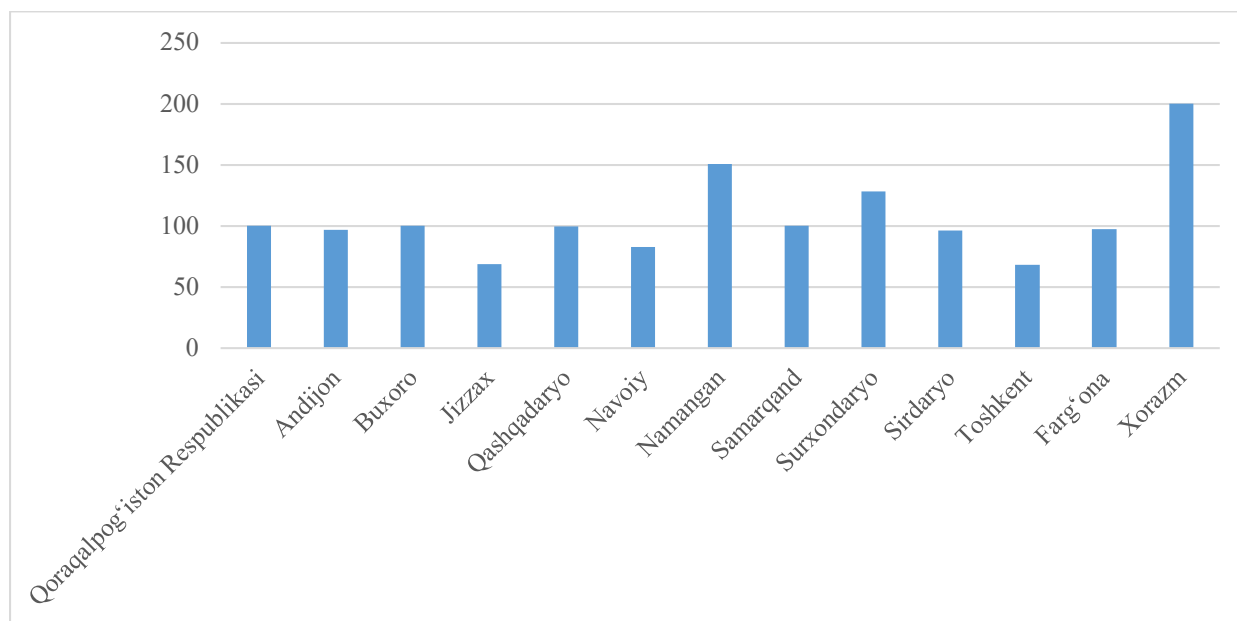


Figure 1. Rate of Plan Fulfillment for the Distribution of Oltinko'z by Region³

² author's development

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In the remaining regions, plan fulfillment ranged from approximately 82% to 100%, indicating a relatively close correspondence between planned and actual implementation. This suggests that the activities of regional biolaboratories were generally well coordinated and effectively managed.

Overall, although the nationwide distribution of the Oltinko'z biological product slightly exceeded the planned target, the substantial regional differences highlight the importance of improving regional planning mechanisms, strengthening monitoring systems, and enhancing the allocation of biological resources to ensure a more balanced and efficient implementation of biological plant protection measures.

2. Assessment of the Distribution Density of Biological Products. The next stage of the analysis examines the distribution density of biological products by determining the number of millions of biological units applied per hectare in each region. In modern plant protection systems, evaluating the effectiveness of biological control requires not only measuring the total quantity of biological products distributed but also assessing the intensity of their application across cultivated areas.

In particular, the distribution density of the Oltinko'z biological product on wheat fields—expressed as the number of millions of biological units applied per hectare—serves as an important indicator of resource utilization efficiency and the quality of biological protection measures.

This density indicator provides more than a comparative measure of the planned and actual quantities of biological products distributed across regions. It also enables a detailed assessment of the efficiency of biological control practices, the balance of regional resource allocation, and the operational performance of biolaboratories. Furthermore, it provides a statistical basis for identifying regional disparities and improving future planning and management of biological plant protection programs (Table 3).

$$\text{Biological Product Density} = \frac{\text{Quantity (mln units)}}{\text{Hectares of Wheat}}$$

Table 3

Wheat Area and Biological Product Density by Regions of Uzbekistan⁴

No	Region Name	G'alla maydoni (ga)	Miqdor (mln.dona)	Zichlik (mln.dona/ga)
1	Qoraqalpog'iston Respublikasi	63,000	62.9	0.998
2	Republic of Karakalpakstan	82,000	79.6	0.971
3	Andijan	76,894	77.1	1.003
4	Bukhara	105,000	72.3	0.688
5	Jizzakh	140,000	139.1	0.993
6	Kashkadarya	38,039	31.4	0.826
7	Navoi	68,000	102.5	1.507
8	Namangan	77,123	77.1	1.000
9	Samarkand	89,324	114.5	1.282
10	Surkhandarya	78,000	75.1	0.963
11	Syrdarya	103,000	70.3	0.682
12	Tashkent	94,770	92.5	0.976
13	Fergana	33,200	66.4	2.000

This table presents data on wheat cultivation areas, distribution volume, and wheat treatment density, expressed in million units per hectare, across various regions of Uzbekistan. The following key aspects should be taken into account when conducting a general analysis of the table.

First, there is significant variation in wheat cultivation areas across the regions of Uzbekistan. The largest wheat-growing areas are observed in Kashkadarya Region, with 140,000 hectares, Jizzakh Region, with 105,000 hectares, and Tashkent Region, with 103,000 hectares. These regions can be considered major centers of wheat cultivation and important contributors to agricultural production. In contrast, regions such as Navoi, with 38,039 hectares, have relatively smaller cultivation areas, which may also correspond to lower distribution volumes.

⁴ author's development

Second, the relationship between wheat treatment density and distribution volume shows considerable regional differences. In Khorezm Region, the treatment density is particularly high, at 2.000 million units per hectare, indicating an intensive application of biological products in wheat fields. This suggests that biological protection measures in Khorezm were implemented at a high level of intensity. In contrast, treatment density is relatively low in Tashkent Region, at 0.682 million units per hectare, and Jizzakh Region, at 0.688 million units per hectare, which may indicate a comparatively lower intensity of biological product application in these areas.

Third, regional differences may be associated with wheat cultivation technologies, soil fertility, climatic conditions, pest pressure, and the organizational capacity of biolaboratories. For example, in Namangan Region, the treatment density is relatively high, at 1.507 million units per hectare, indicating intensive use of biological protection measures. However, in Jizzakh and Tashkent regions, despite their large wheat cultivation areas, the treatment density is lower, which suggests the need to further improve the planning and distribution of biological products (Figure 2).

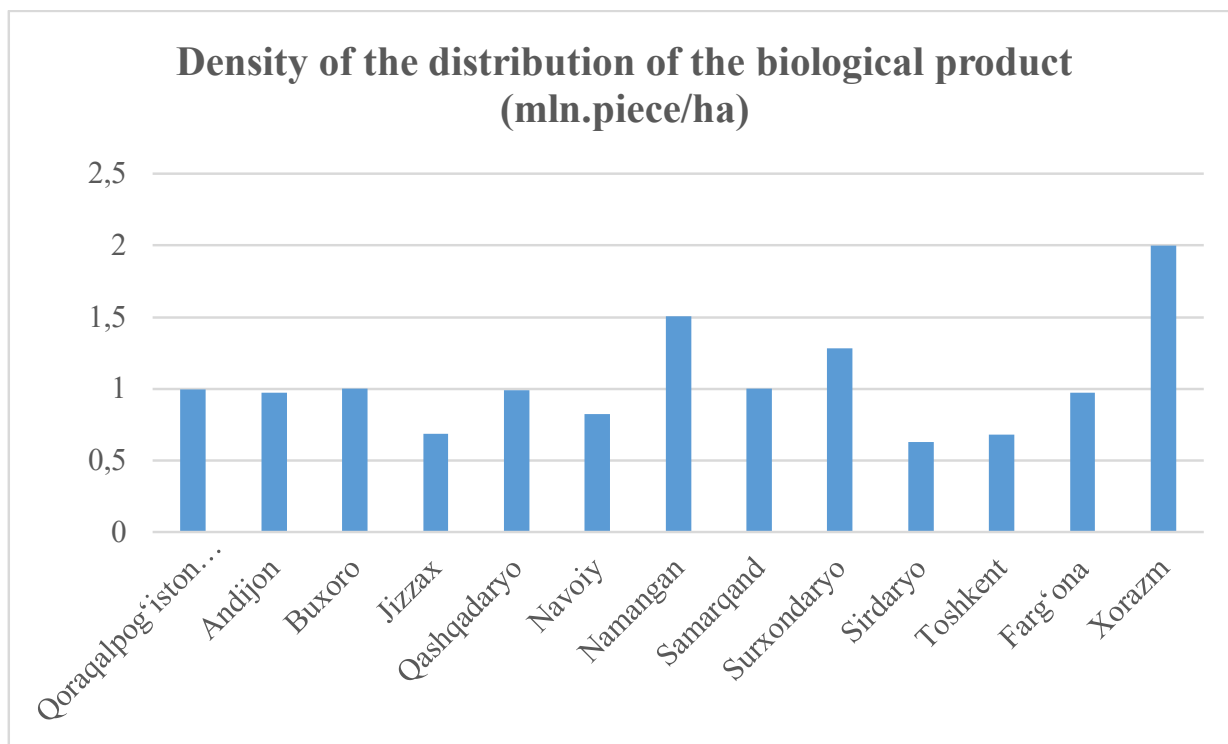


Figure 2. Distribution density of biological product on wheat fields across regions⁵

CONCLUSION AND RECOMMENDATIONS

The analysis of the use of the Oltinko'z biological agent for pest control and preventive measures across the Republic of Uzbekistan in 2024 shows that the overall plan for its application to wheat fields was fulfilled by 101.19%. This indicates a high level of activity in the use of biological agents nationwide and reflects the intensity of agrotechnical measures. In particular, the plan was exceeded in Khorezm, Namangan, and Surkhandarya regions, which may indicate a higher level of pest risk or a greater practical need for biological protection measures in these areas.

At the same time, in Jizzakh and Tashkent regions, the plan fulfillment rate was below 70%. This may be associated with resource limitations, logistical challenges, or certain inaccuracies in regional planning. These discrepancies indicate the need to improve the balanced distribution of biological plant protection agents across the republic.

The analysis based on distribution density indicators shows important regional differences in the intensity of biological product application. In particular, in Khorezm (2.000 million units/ha), Namangan (1.507 million units/ha), and Surkhandarya (1.282 million units/ha), the density of biological products was relatively high, indicating that biological protection measures were organized more intensively in these regions. Conversely, in

⁵ author's development

Tashkent (0.682 million units/ha) and Jizzakh (0.688 million units/ha), this indicator was lower, which suggests the need to strengthen the implementation of biological control measures in these areas.

Based on the results of the study, the following recommendations are proposed:

1. Improve the planning system based on regional needs. Instead of applying a uniform plan for the distribution of biological products, a differentiated approach should be introduced, taking into account pest risk levels, agro-climatic conditions, and pest infestation statistics from previous years.
2. Improve the logistics and supply system. In regions where resources are limited and plans are not fully implemented, particularly in Jizzakh and Tashkent regions, it is necessary to review the logistics chain and the system for supplying biolaboratories with the required resources.
3. Standardize biological product distribution density. Normative indicators should be developed for biological product density in relation to cultivated land in each region, and a monitoring and evaluation system based on these indicators should be introduced.
4. Strengthen coordination among biolaboratories. It is advisable to improve efficiency through the exchange of experience, technological standardization, and comparison of performance indicators among regional biolaboratories.
5. Introduce a digital monitoring and management system. A digital monitoring system should be implemented to track the use of biological products, collect real-time data, and conduct timely analysis. This will improve planning accuracy, resource allocation, and the overall effectiveness of biological plant protection measures.

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Proofreader: Xondamir Ismoilov
Layout and Designer: Oloviddin Sobir ugli

2026. № 5

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