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IN VITRO USULI ASOSIDA KARTOSHKA URUG‘CHILIGINING IQTISODIY SAMARADORLIGINI OSHIRISH YO‘LLARI

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Annotatsiya. Ushbu maqolada in vitro usuli yordamida kartoshka urug‘chiligini ko‘paytirishning iqtisodiy samaradorligi tahlil qilindi. O‘zbekiston sharoitida
In vitro ko‘paytirish orqali 1 yilda milionlab sog‘lom o‘simliklar ishlab chiqarish mumkin, bu esa an’anaviy ko‘paytirish usulga nisbatan 2 baravargacha hosildorlikni oshiradi. Shu bilan birga, urug‘lik yetishtirishda kuzatiladigan yo‘qotish xavfi kamayadi, yuqori sifatli urug‘lik yetkazib berish va barqaror ishlab chiqarish tizimi yo‘lga qo‘yiladi. Mazkur yondashuv oziq-ovqat xavfsizligini mustahkamlash va qishloq xo‘jaligida innovatsion jarayonlarni rivojlantirish imkonini beradi.

Kalit so‘zlar. In vitro ko‘paytirish, kartoshka urug‘chiligi, iqtisodiy samaradorlik, mavjud muammolar, innovatsiyalar, resurslardan samarali foydalanish, urug‘chilik tizimi, hosildorlik hamda oziq-ovqat xavfsizligi.

СПОСОБЫ ПОВЫШЕНИЯ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ РАЗВЕДЕНИЯ КАРТОФЕЛЯ С ИСПОЛЬЗОВАНИЕМ IN VITRO МЕТОДА

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Аннотатсия. В данной статье проанализирована экономическая эффективность размножения семенного картофеля с использованием метода in vitro. В условиях Узбекистана с помощью in vitro микроклонального размножения можно за один год получить миллионы здоровых растений, что позволяет увеличить урожайность до двух раз по сравнению с традиционными методами размножения. При этом снижаются потери, наблюдаемые при производстве семенного материала, обеспечивается поставка высококачественных семян и создаётся устойчивая система производства. Данный подход способствует укреплению продовольственной безопасности и развитию инновационных процессов в сельском хозяйстве.

Ключевые слова. In vitro размножение, семеноводство картофеля, экономическая эффективность, существующие проблемы, инновации, эффективное использование ресурсов, система семеноводства, урожайность, продовольственная безопасность.

WAYS TO INCREASE THE ECONOMIC EFFICIENCY OF POTATO SEED PRODUCTION USING THE IN VITRO METHOD

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Abstract: This article analyzes the economic efficiency of potato seed production using the in vitro method. Under the conditions of Uzbekistan, in vitro micropropagation makes it possible to produce millions of healthy plants within one year, which increases yield by up to two times compared to traditional propagation methods. At the same time, the risk of seed loss is reduced, ensuring the supply of high-quality seed material and the establishment of a stable production system. This approach contributes to strengthening food security and promotes the development of innovative processes in agriculture.

Keywords. In vitro propagation, potato seed production, economic efficiency, existing challenges, innovations, efficient use of resources, seed system, productivity, food security.

INTRODUCTION.

In vitro propagation can produce millions of potato plants per year, significantly increasing yields. This method allows for the conservation of genetics and the protection of potato varieties and their wild counterparts. In traditional propagation, there is a constant risk of seed loss, but in vitro propagation reduces this risk and ensures the production of high-quality seed.

To develop in vitro propagation in Uzbekistan, it is important to equip laboratories, train specialists, support through subsidies and grants, as well as a certification system. It is also necessary to issue permits for local potato seed production through automated systems, identify growers, and maintain their primary register. In particular, it is possible to identify local potato seed producers of high-quality varieties, issue permits for quality potato seed production, and maintain their primary register.

Adapting seed production systems to climate conditions provides economic growth. The problem is that viruses cause a sharp decrease in yield, and virus-infected seeds also damage healthy seeds. The economic use of ware potatoes as seeds complicates the problem. Therefore, strategic, preventive and economic approaches are needed to prevent the spread of viruses and diseases. For example, over the past 150 years, the average temperature has increased by about 1.6°C, an average of 0.001°C over the years. By 2050, temperatures in Central Asia are expected to increase by 1.5-3°C.

LITERATURE REVIEW.

“On the Strategy of Uzbekistan-2030” the priority direction of the Strategy for the Development of Agriculture for 2020-2030 is to increase the local supply of vegetable, melon and potato seeds by 50% (Goal 54), while introducing mechanisms for the production of food products according to the needs of the population.

In accordance with these priority directions, it is preferable to use in vitro propagation. The reason is that in vitro propagation includes practices such as growing, storing and distributing plant materials free from various pathogens. Also, starting from 2025,

it is planned to develop potato seed production in the specialized districts of Korgontepa, Bakhmal, Zomin, Shahrisabz, Kitab, Yangikurgon, Bulungur, Bostonlyk and Sokh districts[1].

In vitro propagation methods have significant technical potential for producing high-quality seed potatoes, saving up to 3 years of time compared to traditional methods, as well as advantages in terms of propagation and phytosanitary status. Commercial implementation of this technology requires infrastructure and cost.[2]. In particular, the use of in vitro technology reduces the disadvantages of seed potato production (such as diseases, slow growth rate, and

[1]Decree of the President of the Republic of Uzbekistan No. PF-158 dated September 11, 2023 and Resolution No. PQ-269.

[2]Conclusions. https://www.mdpi.com/2223-7747/14/17/2777.

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yield losses). This increases economic benefits in the agricultural system and ensures sustainable production.[3].

Potatoes provide the most energy per unit area and can be 74.5% higher in terms of material yield than wheat and 58% higher than rice. The planting date of potatoes is determined by the length of the growing season in the region, and late planting reduces yields.[4]. Potato seed production is expensive and accounts for about 40% of production costs. In many cases, small tubers or large tubers are planted in sections to reduce costs. The use of biofertilizers also helps reduce the cost of potato seed production and provides environmental benefits.[5]. In vitro-grown seed potatoes are essential for productivity and sustainability in potato production. The use of disease-free and well-germinated seed potatoes reduces disease, reduces the need for agrochemicals, and promotes environmentally friendly farming practices[6].

RESEARCH METHODOLOGY.

In ensuring food security, modern biotechnology, genetic modification, conservation of genetic resources and selection methods are also based on scientific and practical methods of agricultural economics. Also, scientific conclusions from studies on the development of potato seed production based on foreign experience are used. Therefore, methodological analyses are important in increasing economic efficiency (Figure 1).That is why, Scientific, theoretical and practical recommendations have been developed to increase the economic efficiency of potato seed production based on in vitro propagation. In particular,The integrated development of foreign and local selection achievements in potato cultivation, economic analysis and use of new opportunities for efficiency, as well as the analysis of scientific approaches and new mechanisms for economic efficiency were forecasted.

1. Source of capitalto determine	**2. Financial resources opportunities**
Funding can be obtained from the budget, private investments, international financial institutions, bank loans, or grants. Investment attraction and partnership opportunities are being evaluated.	An analysis of the terms, interest rates, and repayment terms of financial sources is carried out. Assessing the possibility of government benefits and subsidies.
3. Financing	**4. Product development**

[3]Silva Agurto, C.; Leiva Mora, M.; Sanchez Ortiz, N.; Del Castillo Bastidas, D. Influence of lighting conditions on the in vitro bud set of Solanum tuberosum L. var. Cecilia. Bionatura 2023, 8, 1-9. Available online: http://revistabionatura.com/2023.08.03.9.html (accessed on 26 April 2025).
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[4]Bangladesh Agron. J. 2017, 20 (1): 25-29 p.
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A complete cost estimate (equipment, labor, raw materials) is prepared for the production process. A financial allocation for purchases and services will be developed. It also takes into account the analysis and how costs will be covered.	Agrotechnical measures in seed production. Control and quality management. Indicators of yield and product characteristics.
5. Sales and profit	**6. Net profit**
Market analysis, pricing strategy, and sales channels (domestic and export) are studied. The total revenue from the sale of the product is calculated. Future market share and profit potential are taken into account.	Net profit (profitability) is determined by subtracting expenses from revenue. Economic efficiency indicators are analyzed mathematically.

Figure 1. Methodological approaches to increasing the economic efficiency of potato seed production based on the in vitro method.

ANALYSIS AND DISCUSSION.

The introduction of in vitro propagation into domestic production provides opportunities to increase economic efficiency, provide the domestic market with quality seeds, and open the way for exports. Various factors (problems and opportunities) affecting potato yield determine economic efficiency. Negative factors of global climate change limit the possibilities of profit. Also, the use of in vitro technology in the potato seed production system allows for the production of high-quality and virus-free seed material. This significantly improves economic efficiency by increasing yields, reducing the spread of diseases, and reducing production costs.
The experience of Russia, Belarus, the Netherlands, Germany, France, Spain, Italy, Great Britain, Poland, China, India, Pakistan, Egypt, Iran, Argentina, Brazil, the USA and Canada was studied. The state strategies adopted in these countries for the development of potato seed production were studied. Based on this, the organizational and economic foundations of potato seed production were developed in the research work (Figure 2).

Figure 2.Based on monographic analysescopyrighted work.

1. Implementation of state programs
2. Strengthening the legislative framework
3. Allocation of subsidies, loans, and government grants
4. Establishing research, education, and quality control
5. Development of high-quality potato seed production
6. Improvement of infrastructure and agronomic practices
7. Establishing a transparent competitive environment
8. Establishing a certification system
9. Adaptation to market relations

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Typically, about 40-50 micronodules can be formed from one in vitro plant, and 8-10 mininodules can be formed under the netting conditions of nurseries.[7]In addition, in vitro propagation methods have significant technical potential for producing high-quality seed potatoes, saving up to 3 years of time compared to traditional methods, as well as having advantages in terms of propagation and phytosanitary status. For commercial purposes, the widespread implementation of this technology requires infrastructure and costs[8].

Development of practical, organizational and economic mechanisms for in vitro propagation, integrating local selection achievements in potato seed production, as well asIt is necessary to expand the use of biotechnology and strengthen the organizational foundations of potato seed production (Figure 3).

Figure 3. Organizational and economic foundations of potato seed production. Authorship development

Organizational basis of the potato seed production system	Economic basis of the potato seed production system
• **Seed Production.** Cooperation will be established among seed production enterprises, scientific laboratories, and farming enterprises. • **Science Integration.** Development of scientific institutions engaged in modern biotechnology, virus-free seed production, and breeding activities. **Supply Chain.** Coordination of seed preparation, storage, transportation, and distribution processes. **Financial Support.** Provision of funds to producers through credits, subsidies, banks, and government programs. **Market.** Development of markets for seed sales, export routes, and logistics systems.	• **Production Efficiency.** Ensuring high yields with minimal costs through quality seeds and market competitiveness. **Investments and Capital.** Attracting government, private sector, and foreign partners to the seed industry, and allocating funds for the implementation of advanced technologies. **Price Stability.** Establishing stable prices in the seed and potato markets to increase farmers' income. **Safety and Risk Management.** Adapting to climate change and the dynamics of the market economy. **Local Products.** Reducing imports and supporting the national economy through the use of high-quality domestic seeds.

In vitro microtubers are small potato tubers (4-12 mm in size) that are grown in the laboratory. Minitubers are usually grown in soilless mixtures, containers, or hydroponics in greenhouse conditions.[9]. The small size and weight of micro tubers provide a great advantage in production. In fact, micro tubers can be directly sown in the soil and mass-produced throughout the year, with morphological and biochemical characteristics that are almost identical to those of field-

[7]Buckseth T., Singh RK, Tiwari JK, Sharma AK, Singh S., Chakrabarti SK (2020). A novel sustainable aeroponic system for healthy seed production in India - an update. Indian J. Agric. Sci. 90 (2), 243-248.

[8]Conclusions. https://www.mdpi.com/2223-7747/14/17/2777.

[9]Wróbel, S. Assessment of potato microtuber and in vitro plantlet seed multiplication in field conditions-Growth, development and yield.

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grown crops. Therefore, the production of micro tubers could revolutionize the global potato industry[10].

For reference, the global seed potato market size was US$13.9 billion in 2024 and is expected to reach US$16.6 billion by 2030. The seed potato industry is projected to grow at a CAGR of 2.97% during 2024-2031[11].

Today, in Uzbekistan, the average yield of seed potatoes grown in traditional ways is 20-25 tons/ha, and costs are high - especially for pesticides and seed renewal. With in vitro propagation, the yield increases to 30-35 tons/ha, due to high-quality seeds, costs are reduced, and profits can increase by 30-40%. For example,A total of 16.2 kg of fertilizer is used to produce 1 ton of potato products and stems, consisting of 6.2 kg of nitrogen, 2 kg of phosphorus, and 8 kg of potassium. Areas with close groundwater during the potato growing season Watered 4-7 times, and in deep areas 8-9 times[12].

ASPECTS	TRADITIONAL METHOD	BIOTECHNOLOGICAL METHOD
Quality	Naturally obtained semen is at high risk of exposure to viruses	Virus-free, pure seed, stability
Productivity	Average: 20-25 tons/ha	Average: 40-50 tons/ha
Yield stability	Variable	Stable and highly efficient
Costs	Low costs for seed collection and storage	High costs for laboratory and technological equipment
Technical complexity	Technology is simple and outdated approaches	Qualified personnel and a laboratory are needed, a scientific approach is taken
Economic efficiency	Financial productivity is average, expenses are relatively low	Productivity is high and costs are also higher
Risks	Viruses, damage, yield reduction	There are laboratory problems and financial risks.
Import dependence	Insufficient seed resources, greater dependence on imports	Increases seed resources, reduces need for imports
Positive impact	Jobs will increase. The traditional method will continue.	High-quality products are obtained, export opportunities increase

Figure 4. Analysis of traditional and biotechnological methods in potato seed production. Authorship development.

[10]Kanwal Amina, AA and K. Shoaib (2006). In Vitro Microtuberization of Potato (Solanum tuberosum L.) Cultivar Kuroda-A New Variety in Pakistan. International Journal of Agriculture and Biology 8(3):337-340.
[11]https://www.cognitivemarketresearch.com/seed-potatoes-marketreport.
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Three factors influence the efficiency of economic growth: the labor, material, and capital requirements of the gross domestic product. It is also possible to increase the added value by creating a complete value chain that includes processing, storage, logistics, and marketing. Once you have identified the resources and operations needed to grow potatoes, it is important to know whether this business is profitable or not. To determine this, the costs incurred and the revenue generated from the harvest are calculated. This is called a "Gross Margin Analysis" or in some cases, a "Cost-Benefit Ratio".

$$\text{Gross Margin \%} = \frac{\text{Revenue - price of goods/services}}{\text{Income}} * 100\ \%$$

GM (Gross Margin) is the difference between the total revenue from selling potatoes and the total costs of growing them.

Here, COGS = revenue - cost of goods/services (Cost of Goods Sold, COGS)[13]. For example, if up to 2,000 tons of super-super elite seeds are produced from protected greenhouses (1 kg of super-super elite seeds is sold for 10,000 soums), the total revenue (20 billion-16 billion soums) will be 4 billion soums, and the cost of goods and services during cultivation will be 2 billion soums, the difference between total revenue from seed sales and costs will be 50%.

In potato production, economic efficiency also indicates the level of cost of inputs in the production process. It represents the profit in relation to the cost of the product produced.

$$\text{Gross Margin \%} = \frac{\text{4 billion soums-2 billion soums}}{\text{4 billion soums}}\ 100\ \% = 50\ \%$$

Economic efficiency can be calculated using the following formula:

$$IS = \frac{\text{Income}}{\text{Total cost}}$$

UX-Total costs incurred to produce the product.

IS>1-production is economically efficient, i.e. revenue is greater than costs. IS<1-production is economically inefficient, i.e. costs are greater than revenue.

[13]"National potato council of Kenya, a guideline for farmers and trainers"//Potato production handbook, 2018. 91-95.

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STAGE 1		
Year 1. Extra-budgetary funds will be generated for allocation to scientific institutions and business entities on a competitive basis.	**Year 1.** 400,000 in vitro plants are produced in 5 laboratories every 3 months; - 1 piece up to 5-8 microplants are obtained from an in vitro plant, with a germination rate of 85%; - 2 million micro-tubers are grown in 5 months; - On average, 83-85 thousand micro tubers can be planted per hectare.	**Year 1.** 2 million micro-nodes per hectare in greenhouses If 83 thousand seeds are planted 24 hectares of protected greenhouses will be needed; - 5 mini nodes can be obtained from 1 micro node; - 10 million mini-tubers can be grown in 24 hectares of protected greenhouses.
STAGE 2		
Year 2. A Republican Commission is formed; - opportunities will be explored in districts with areas located at an altitude of 800-1000 meters above sea level; - 120 hectares of selected farmers and peasant farms will be identified; - 10 million mini-tuberculosis vaccines will be distributed free of charge.	**Year 2.** 2,5 thousand tons of high-generation super-super elite seeds will be grown on 120 hectares of land; - an average of 20 tons of crop can be obtained from 1 hectare; - super-seper elite seeds will be sold to the Kurgan-tepa, Bahmal, Zamin, Kitab, Shahrisabz, Yangikurgan, Bulungur and Sokh districts.	**Year 2.** Supervision and monitoring activities are systematically carried out by the Republican Commission; - potato sales will be organized under the responsibility of local khokimiyats; - proposed model it requires a period of 5 years.
STAGE 3		
Year 3. 25,000 tons of high-generation super-elite seeds will be grown on 1,000 hectares of farms and dehkan farms in 40 districts; - On average, 2.5 tons are planted per hectare, and the yield can be up to 25 tons per hectare.	**Year 4.** 250 thousand tons of crops are harvested from 10 thousand hectares; -60% of the harvest - 150 thousand tons of elite seeds are obtained.	**Year 5.** 150,000 tons of elite seeds will be planted on 50,000 hectares in the regions; - it is possible to harvest 1 million 250 thousand tons of maize and 2 million 500 thousand tons of poppy; -yield R1 is divided into seed and consumption.

Figure 5. 3-step in vitro propagation mechanism.

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If 1 kg of cultivated elite seeds is sold for an average of 10 thousand soums, it will be worth 1.5 trillion soums, if 1 kg of R1 seeds is sold for 5 thousand soums, it will be worth 6.75 trillion soums, and if 900 thousand tons of consumer potatoes are sold for 3 thousand soums, it will be worth 2.7 trillion soums. Then the $ 1.5 million allocated by the state for the cultivation of 400 thousand in vitro plants in laboratory conditions will be covered by export and tax revenues. The domestic market will be fully supplied with potatoes.

Economic efficiency shows the level of resource prices in the production process. Where: D-Income. UX-total cost of production. In 5 in vitro laboratories in Uzbekistan, it takes an average of more than 4 billion soums to grow 2 million in vitro plants for 3 months. 10 thousand mini-roots are obtained from protected greenhouses, and up to 2.5 thousand tons of super-super elite seeds are obtained from mini-roots. The cost of 1 kg of seeds is 8 thousand soums (5.5 thousand soums for cultivation, 2.5 thousand soums for storage). As a result, if 1 kg of super-super elite seeds is sold for an average of 10 thousand soums, the total income will be 20 billion soums. Here, IS=4.8 (IS>1), that is, economic efficiency (4 times) is ensured.

CONCLUSION AND SUGGESTIONS.

Identifying the most important constraints in the potato sector and identifying the right areas for innovative research will accelerate the integration of agricultural systems and traditional development goals, and improve science and technology. The production and distribution of quality potato seeds will not only increase productivity in rural systems, but also significantly strengthen food security. Access to high-yield and quality seeds will reduce household food insecurity, expand rural income sources, and create a sustainable food supply system. In particular, the use of modern technologies and disease-free seeds in potato production will increase yields and improve production efficiency.

In addition, effective cooperation between potato growers, research centers, plant breeders and traders is also needed. They will exchange experiences, implement new selection and propagation methods, and deliver quality products that meet market needs. Thus, not only will the level of production increase, but also the innovation processes in the agricultural system will accelerate. Also, the in vitro seed production system will allow for efficient use of resources, shorten the production cycle, and increase quality assurance. This approach will play an important role in ensuring the sustainability of potato cultivation and strengthening food security.

Based on the above, in potato seed production3-step in vitro propagation mechanism It is also proposed to establish and introduce modern technologies, expand the production of certified seed material. It is also proposed to improve the economic evaluation system and strengthen cooperation between research institutions and production enterprises.

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