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“CULTIVATION OF ICEBERG LETTUCE USING THE HYDROPONIC METHOD IN OPEN AND CLOSED AREAS AND THE ORGANIZATION OF PRIMARY SEED PRODUCTION”

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Abstract: The study investigates hydroponic cultivation of “Iceberg” lettuce in open and closed systems, including primary seed production. Greenhouse conditions resulted in earlier maturation and higher yields compared to open-field cultivation. The findings demonstrate the effectiveness of hydroponics and the importance of adapting varieties to local conditions for improved productivity and quality.

Keywords: *Iceberg lettuce, hydroponics, open-field and greenhouse cultivation, yield, primary seed production, varieties*

Introduction: Today, providing the population with high-quality, ecologically clean, and biologically beneficial vegetable products is one of the priority directions of the agro-industrial complex. Hydroponic cultivation technology is considered an advanced agro technology characterized by high efficiency and water-resource conservation. This method enables the effective cultivation of various vegetables, including Iceberg lettuce, in both open and closed (greenhouse) environments.

Iceberg lettuce (*Lactuca sativa* var. *crispa*) is distinguished by its high consumer value, nutritional content, and dietary properties. Rich in vitamins, minerals, and fiber, it remains one of the high-demand vegetable crops in the global market. However, the production volume of Iceberg lettuce in our country and research based on diverse agro technologies remain insufficient.

Cultivating Iceberg lettuce through hydroponics yields high efficiency, particularly in regions with unfavorable climates or limited water resources. Furthermore, producing high-quality seeds is one of the critical challenges in

contemporary agricultural science and practice. By organizing primary seed production, it is possible to satisfy domestic demand, reduce dependence on imported seeds, and develop varieties adapted to local conditions. From this perspective, developing the scientific and practical foundations for the hydroponic cultivation of Iceberg lettuce in open and closed areas, as well as the organization of primary seed production, is a highly relevant issue today. Greenhouse vegetable production is a key branch of agriculture, playing a vital role in providing the population with fresh, vitamin-rich products during the off-season.

The purpose, objectives, and significance of the study

Current status and policy: Presently, the total area of hydroponic greenhouses in our republic is expanding annually, a trend driven by the high economic efficiency of this sector. To ensure the extensive development of this field, several decrees and resolutions have been adopted by our state.

Global context and statistics: Globally, the production volume of leafy green vegetables essential for human health, particularly head lettuce, is increasing every year. In 2020, global lettuce production reached 27.66 million tons. China holds the leading position, accounting for the largest share at 14.32 million tons. Following China, the United States produced 4.40 million tons, India 1.12 million tons, Spain 969.06 thousand tons, and Italy 735.47 thousand tons. The remaining global output is distributed among other countries.

Scientific trends: In leading countries such as those in Europe, China, Japan, and Russia, scientific research is being conducted on the ear-round cultivation, storage, and processing technologies of more than 25–30 types of vegetables. These nations are developing and implementing new varieties of head lettuce into production. Research is focused on creating high-yielding, early-maturing varieties that are rich in biologically active substances and resistant to pests, diseases, and unfavorable weather conditions. Acclimatizing

new varieties of head lettuce, improving cultivation technologies, and expanding primary seed production capabilities are of paramount importance.

National perspective: In our republic, only 20–25 types of major vegetables and 4–5 types of leafy greens are currently cultivated. Great emphasis is now being placed on increasing the agro-biodiversity of leafy green vegetables, studying the morph-biological and valuable economic traits of new crops, localizing promising variety samples, developing cultivation technologies, and organizing primary seed production.

Relevance of the research. According to Decree No. PF-60 of the President of the Republic of Uzbekistan, dated January 28, 2022, "On the Development Strategy of New Uzbekistan for 2022–2026," one of the critical strategic tasks is "reducing the areas sown with cotton and grain crops and planting potatoes, vegetables, fodder, and oilseed crops in the vacated lands." Consequently, expanding the diversity of leafy green vegetables, acclimatizing head lettuce varieties, and developing scientific foundations for promising agro technologies aimed at obtaining high-quality, biologically active, and medicinal yields ear-round—alongside expanding lettuce seed production—is a highly relevant issue for the country, particularly in the Andijan region.

This dissertation research contributes to the implementation of tasks outlined in the "Strategy for the Development of Agriculture of the Republic of Uzbekistan for 2020–2030," as well as Cabinet of Ministers Resolution No. 504, dated August 25, 2020, "On measures to restore local varieties of agricultural crops with unique characteristics at risk of extinction and organize their original seed production," and other regulatory documents.

Research object and experimental methods. The research was primarily conducted during 2022–2024 (partially during the 2021 autumn-winter turnover) at the following locations:

- The lands of "Mega Agro" LLC in the Pakhtaabad district of the Andijan region.

- The experimental farm of the **Andijan Institute of Agriculture and Agro technologies**.
- The lands of "**Modern Greenhouses Complexes**" LLC in the Asaka district of the Andijan region.

Soil conditions: The studies were carried out on the stony lands of "Mega Agro" LLC, the gravelly soils of the Andijan Institute of Agriculture and Agro technologies, and the adyr (foothill) lands of "Modern Greenhouses Complexes" LLC. Due to the limited possibilities of traditional soil utilization in these areas, particular importance was placed on the **hydroponic method** of vegetable cultivation.

Climatic conditions: According to the soil-climatic zoning of Uzbekistan, certain areas of the Andijan region are located in the semi-desert zone with typical gray (serozem) soils. The climate of the Andijan region is characterized by significant fluctuations in annual and daily temperatures, low and unevenly distributed precipitation throughout the year, high air and soil temperatures in summer, low temperatures in winter, high atmospheric aridity, and intense moisture evaporation from the soil.

Research objects and varieties. The following imported and local varieties of Iceberg lettuce were selected as the objects of the research:

- **Krupnokachan** (Russia)
- **Great Lakes 118** (USA)
- **Iceberg** (USA)
- **Robinson** (Netherlands)
- **Kok Shokh** (Uzbekistan) – A locally adapted variety.

The following **hydroponic systems** were utilized during the research.

| № | System Type | Brief Description |
|---|-------------------------------------|--|
| 1 | NFT (Nutrient Film Technique) | A continuous nutrient solution flow within a water channel (trough). |
| 2 | Substrate-based (Coconut coir/pith) | Cultivation using a solid substrate |

| | |
|--|-------------------|
| | (growing medium). |
|--|-------------------|

Environmental Control and Technical Parameters. In the hydroponic systems, the following parameters were strictly monitored:

- **ph Level:** 5.8–6.5
- **Electrical Conductivity (EC):** 1.2–1.8 mS/cm
- **Temperature:** 18–22°C

Agro-ecological conditions:

- **Open Field:** Wind, temperature, and humidity remained subject to natural environmental conditions.
- **Closed Environment (Greenhouse):** Automated control was maintained with temperatures between **20–25°C** and relative humidity at **60–70%**.

Research results and discussion. The analysis of Iceberg lettuce varieties cultivated in the Andijan region revealed significant agro-biological differences between open and closed environments. Despite using identical varieties, seeds, and agrotechnical methods, the change in environment led to fundamentally different outcomes.

1. Iceberg Variety

- **Open Field:** Matured in 45 days with a yield of **37.1 t/ha** and an average head mass of **390 g**.
- **Closed Environment:** The growth period decreased to **39 days** (6 days earlier). Yield increased to **39.3 t/ha** (a **5.9%** increase), and head mass rose by **5.1%** to **410 g**.
- **Conclusion:** Greenhouse cultivation accelerated growth and enhanced marketability.

2. Krupnokachan Variety

- **Open Field:** Yielded **34.1 t/ha** in 45 days with a head mass of **370 g**.
- **Closed Environment:** Demonstrated a significant "rebound" effect, maturing in 39 days. Yield soared to **39.0 t/ha** (a **14.4%** surge), and head mass reached **400 g** (an **8.1%** increase).

- **Conclusion:** Its dense and firm heads make it one of the most reliable varieties for greenhouse production.

3. Great Lakes 118

- **Open Field:** Matured in 42 days with a yield of **32.5 t/ha**. Lower density and some instances of damage were observed.
- **Closed Environment:** Performance improved drastically, maturing in 38 days (4 days earlier). Yield reached **36.2 t/ha (11.4% growth)**, and head mass increased by **5.4%** to **390 g**.
- **Conclusion:** This variety achieved "commercial standard" quality under controlled conditions.

4. Robinson Variety

- **Open Field:** Affected by water scarcity, it yielded **24.4 t/ha** in 45 days with a head mass of **350 g**.
- **Closed Environment:** Matured in 40 days (5 days earlier). Yield increased to **26.8 t/ha (9.8% growth)**, and head mass rose to **370 g**.
- **Conclusion:** The controlled environment served as a "buffer" against the stress factors seen in open fields.

5. Kok Shokh Variety

- **Open Field:** Yielded **23.4 t/ha** in 44 days with a minimal head mass of **310 g** due to water limitations.
- **Closed Environment:** Showed the most surprising improvement, maturing in 40 days. Yield rose to **26.8 t/ha (14.5% growth)**, while head mass jumped by **17.7%** to **365 g**.
- **Conclusion:** This variety fully realized its biological potential only within the closed hydroponic system.

Comparative summary of Iceberg lettuce varieties (Andijan region)

| № | Variety name | Cultivation type | Growth period (days) | Yield (t/ha) | Head mass (g) | Appearance | Specific differences and |
|---|--------------|------------------|----------------------|--------------|---------------|------------|--------------------------|
| | | | | | | | |

| | | | | | | | conclusions |
|---|-----------------|---------------|----|------|-----|--------------|--|
| 1 | Iceberg | Open field | 45 | 37.1 | 390 | Good | Climate-stable; larger lower leaves. |
| | | Closed system | 39 | 39.3 | 410 | Excellent | Heat-responsive; high commercial value. |
| 2 | Krupnokachan | Open field | 45 | 34.1 | 370 | Good | Climate-stable; larger lower leaves. |
| | | Closed system | 39 | 39.0 | 400 | Dense & Firm | Heat-responsive; high commercial value. |
| 3 | Great Lakes 118 | Open field | 42 | 32.5 | 370 | Moderate | Lower density; higher incidence of damage. |
| | | Closed system | 38 | 36.2 | 390 | Dense & Firm | Dense heads; clean and commercially attractive. |
| 4 | Robinson | Open field | 45 | 24.4 | 350 | Moderate | Growth stunted due to water scarcity. |
| | | Closed system | 40 | 26.8 | 370 | Good | Developed effectively under hydroponic conditions. |
| 5 | Kok Shokh | Open field | 44 | 23.4 | 310 | Moderate | Growth stunted due |

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|--|--|---------------|----|------|-----|----------|--|
| | | | | | | | to water scarcity. |
| | | Closed system | 40 | 26.8 | 365 | Moderate | Developed effectively under hydroponic conditions. |

Yield performance and statistical stability of Iceberg lettuce varieties in closed hydroponic systems (2022–2024)

Iceberg variety analysis: Between 2022 and 2024, the "Iceberg" variety demonstrated stable and high yield performance in a closed environment. In 2022, the average yield for this variety was 37.0 t/ha. The variance between replicates remained minimal, showcasing high stability with a Standard Error (SE) of ± 0.17 . During this year, the growth initiated under favorable conditions, and the quality of each head was remarkably consistent.

In 2023, the "Iceberg" variety showed further efficiency, with the average yield rising to 38.4 t/ha, representing a +1.4 t/ha increase compared to 2022. The variety adapted rapidly to the controlled agro-climatic conditions, producing dense and high-quality heads. The peak performance was recorded in 2024 at 39.0 t/ha (SE ± 0.23). These results confirm the superior yield capacity and stability of the "Iceberg" variety, not only in terms of quantity but also regarding head density and commercial marketability.

Performance of other varieties: Other varieties in the closed environment also exhibited steady growth trends:

- Great Lakes 118: The average yield was 33.4 t/ha in 2022, 34.8 t/ha in 2023, and reached 36.2 t/ha in 2024. Maintaining an SE of ± 0.19 – 0.21 , this variety demonstrated an 8.0% yield growth over the three-year period.
- Krupnokachan (Control): Recorded yields of 31.5 t/ha in 2022, 33.0 t/ha in 2023, and 34.4 t/ha in 2024. The low SE values indicate highly stable

results within a narrow range, with an overall growth of 9.0% from 2022 to 2024.

- Robinson and Kok Shokh: These varieties showed slightly higher SE values, indicating minor fluctuations in results. In 2024, the average yield for Robinson was 26.7 t/ha, while Kok Shokh reached 26.8 t/ha. Although these varieties are productive, they do not match the high yield and stability levels of "Iceberg," "Great Lakes 118," and "Krupnokachan."

Table: Yield indicators of Iceberg lettuce varieties in closed environments (2022–2024) and average values by replicates (t/ha)

| № | Variety name | Year | Replicate I | Replicate II | Replicate III | Mean ± SE |
|----|-------------------------------|------|-------------|--------------|---------------|--------------------|
| 1 | Iceberg | 2022 | 37.3 | 36.7 | 37.0 | 37.0 ± 0.17 |
| 2 | | 2023 | 38.1 | 38.7 | 38.4 | 38.4 ± 0.17 |
| 3 | | 2024 | 38.6 | 39.4 | 39.0 | 39.0 ± 0.23 |
| 4 | Great Lakes 118 | 2022 | 33.5 | 33.0 | 33.8 | 33.4 ± 0.21 |
| 5 | | 2023 | 34.8 | 35.1 | 34.5 | 34.8 ± 0.19 |
| 6 | | 2024 | 36.2 | 35.8 | 36.4 | 36.2 ± 0.19 |
| 7 | Krupnokachan (Control) | 2022 | 31.4 | 32.0 | 31.2 | 31.5 ± 0.25 |
| 8 | | 2023 | 32.7 | 33.3 | 33.0 | 33.0 ± 0.19 |
| 9 | | 2024 | 34.8 | 34.0 | 34.4 | 34.4 ± 0.22 |
| 10 | Robinson | 2022 | 25.7 | 26.2 | 25.9 | 25.9 ± 0.15 |
| 11 | | 2023 | 27.0 | 27.5 | 27.1 | 27.2 ± 0.15 |
| 12 | | 2024 | 26.8 | 26.3 | 27.0 | 26.7 ± |

| | | | | | | |
|-----------|------------------|------|------|------|------|--------------------|
| | | | | | | 0.21 |
| 13 | Kok Shokh | 2022 | 24.5 | 28.3 | 26.8 | 26.5 ± 1.11 |
| 14 | | 2023 | 25.1 | 27.8 | 25.4 | 26.1 ± 0.85 |
| 15 | | 2024 | 27.7 | 26.2 | 26.5 | 26.8 ± 0.46 |

General conclusion: The most effective and stable yield in closed environments was recorded in the Iceberg variety. Its productivity grew consistently from 2022 to 2024, reaching a peak of 39.0 t/ha in 2024. The Iceberg variety also ranked first in terms of yield stability, head density, and commercial marketability. While Great Lakes 118 and Krupnokachan also demonstrated high results, they remained slightly behind the Iceberg variety regarding both the Standard Error (SE) values and total biomass.

Impact of cuttings (harvest cycles) on seed yield and quality: Experiments conducted between 2022 and 2024 revealed that an increase in the number of cuttings (harvesting cycles) in Iceberg lettuce varieties significantly negatively impacts seed yield and quality.

- Iceberg (2022): Without any cuttings, the seed yield reached up to 410 kg/ha. However, after two cycles of harvesting (cuttings), this figure dropped to 250 kg/ha.
- Great Lakes 118 (2022): The seed yield without cuttings was 390 kg/ha, which decreased to 260 kg/ha after two cycles. Concurrently, seed germination dropped from 92% to 85%, and varietal purity declined from 99% to 94%.
- Krupnokachan (2023): A similar trend was observed; seed yield fell from approximately 400 kg/ha (no cuttings) to 240 kg/ha after two cycles, with corresponding decreases in germination and purity.
- Robinson (2023): Seed yield decreased from 375 kg/ha to 245 kg/ha after two cycles of harvesting.

- Kok Shokh (2024): The seed yield was recorded at 380 kg/ha without cuttings, 340 kg/ha after one cutting, and significantly dropped to 230 kg/ha after two cuttings.

Scientific synthesis: These results indicate that repeated cutting of the plant for foliage production depletes the energy required for optimal seed formation. For high-quality primary seed production, minimizing the number of vegetative harvests is essential to preserve the plant's reproductive potential.

Impact of Harvest Cycles (Cuttings) on Seed Yield and Quality

| № | Year | Variety | Number of cuttings (Cycles) | Seed yield (kg/ha) | Germination rate (%) | Varietal purity (%) | Flowering period (days) |
|----|------|-----------------|-----------------------------|--------------------|----------------------|---------------------|-------------------------|
| 1 | 2022 | Iceberg | 0 | 410.0 | 93.0 | 99.0 | 85 |
| 2 | | Iceberg | 1 | 360.0 | 90.0 | 97.0 | 89 |
| 3 | | Iceberg | 2 | 250.0 | 84.0 | 94.0 | 94 |
| 4 | | Great Lakes 118 | 0 | 390.0 | 92.0 | 99.0 | 87 |
| 5 | | Great Lakes 118 | 1 | 350.0 | 90.0 | 97.0 | 91 |
| 6 | | Great Lakes 118 | 2 | 260.0 | 85.0 | 94.0 | 97 |
| 7 | 2023 | Krupnokachan | 0 | 400.0 | 91.0 | 98.0 | 88 |
| 8 | | Krupnokachan | 1 | 330.0 | 89.0 | 96.0 | 93 |
| 9 | | Krupnokachan | 2 | 240.0 | 83.0 | 94.0 | 98 |
| 10 | | Robinson | 0 | 375.0 | 92.0 | 98.0 | 86 |
| 11 | | Robinson | 1 | 345.0 | 88.0 | 96.0 | 91 |
| 12 | | Robinson | 2 | 235.0 | 82.0 | 93.0 | 96 |
| 13 | 2024 | Kok shokh | 0 | 380.0 | 94.0 | 99.0 | 84 |

| | | | | | | |
|----|-----------|---|-------|------|------|----|
| 14 | Kok shokh | 1 | 340.0 | 91.0 | 97.0 | 89 |
| 15 | Kok shokh | 2 | 230.0 | 85.0 | 95.0 | 95 |

The high quality and varietal purity of Iceberg lettuce seeds serve as the primary guarantee for successful breeding and seed production efforts. Proper harvesting, cleaning, and storage technologies are essential for maintaining seed viability and enhancing the productivity of future crops.

The established seed production recommendations for certified Iceberg lettuce varieties are designed to ensure the acquisition of high-quality, highly germinable, and variety-specific seeds. Rigorous monitoring at every stage, the preservation of varietal purity, and strict adherence to agrotechnical standards are fundamental to maintaining the genetic integrity of the variety.



Photo Gallery of Experimental Research

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