

Growing Lettuce Using the Hydroponic Method in Water Pipes in Open Fields

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Abstract

*Lettuce (*Lactuca sativa* var. *capitata*) is one of the most widely consumed and high-value salad crops in the world. In recent years, its cultivation technologies have intensified, with soil-less hydroponic methods and substrate-based cultivation being extensively adopted. In our Republic, these methods enable the efficient use of water and land resources, the production of environmentally friendly products, and the achievement of high, controlled yields from small areas.*

Therefore, selecting lettuce varieties and developing promising agrotechnologies for both open and closed-ground (soil-less) hydroponic conditions in the Republic, specifically within the Andijan region, remains a highly relevant issue today.

INTRODUCTION

Lettuce (*Lactuca sativa* var. *capitata*) is one of the most widely consumed and high-value salad crops in the world. In recent years, its cultivation technologies have intensified, with soil-less hydroponic methods and substrate-based cultivation being extensively adopted. In our Republic, these methods enable the efficient use of water

and land resources, the production of environmentally friendly products, and the achievement of high, controlled yields from small areas.

Therefore, selecting lettuce varieties and developing promising agrotechnologies for both open and closed-ground (soil-less) hydroponic conditions in the Republic, specifically within the Andijan region, remains a highly relevant issue today.

During a visit to the Andijan region on June 17, 2021, the President of the Republic of Uzbekistan, Shavkat Mirziyoyev, reviewed the operations of the innovative greenhouse established by "Mega Agro" LLC in the Pakhtaabad district. He provided specific instructions regarding the technology of growing lettuce using modern hydroponic methods in both open and closed areas. Furthermore, Resolution No. 204 of the Cabinet of Ministers, dated April 21, 2022, titled "*On additional measures for the complex socio-economic development of the Andijan region and improving the living standards of the population for 2022-2026,*" defined tasks for improving women's education, vocational skills, gender equality, and working conditions.

In fulfilling these tasks, the cultivation of lettuce using modern hydroponic methods will significantly contribute to the national economy, particularly in the productive utilization of rainfed and saline lands, as well as the efficient use of small land plots. To this end, research was conducted in the Andijan region to select high-yielding lettuce varieties with superior economic traits and to develop their cultivation technologies under hydroponic conditions.

Methodology. Experiments on growing lettuce varieties in water pipes in open fields were conducted between 2022 and 2024 at the Department of "Fruit-Vegetable Growing and Viticulture" of the Andijan Institute of Agriculture and Agrotechnologies, as well as on the field sites of "Mega Agro" LLC in the Pakhtaabad district.

During the experiment, activities included installing equipment for planting lettuce seedlings in open fields and preparing the facility for cultivation. The system was installed based on Spanish technology, utilizing a polyethylene pipe system with continuous water circulation. Water pipes were arranged on the ground in 6 rows. The pipes are rectangular in shape, but the upper part is open and covered with a special polyethylene film. Each pipe measures 6 meters in length, 20 cm in width, and 10 cm in height. These pipes were connected according to the field's length and hermetically sealed. Pumps, filters, and tubes were installed for water supply, and holes were perforated in the polyethylene film every 30 cm. Subsequently, the working solution prepared for lettuce was released into the pipes from tanks A, B, and C. Macro-fertilizers used included calcium nitrate (CaNO_3), potassium nitrate (KNO_3), magnesium sulfate (MgSO_4), monoammonium phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$), urea ($\text{Co}(\text{NH}_2)$), potassium sulfate (KSO_4), and nitric acid (HNO_3). Micro-fertilizers included boron (H_3BO_2), zinc (ZnSO_4), copper (ZnSO_4), мис (CuSO_4), iron (Fe), and manganese (MnSO_4).

Variety selection trials were conducted with the following lettuce varieties: *Krupnokochan*, *Iceberg*, *Great Lakes 118*, *Robinson*, and *Kokshokh*. Seedlings of all varieties were manually planted into the water pipes in the first decade of March. The planting scheme consisted of 6-row pipes with 20 cm between pipes and 30 cm between plants within each row (20×30 cm). However, 60 cm walkways were left between the 6-row blocks for maintenance and processing.

Plant nutrition and maintenance were carefully managed. Irrigation was provided for 4 minutes every hour during the day and for 4 minutes every 3 hours at night. The electrical conductivity (EC) of the working solution was maintained at 2.0, with a pH of 5.8. By the first decade of April, irrigation frequency was adjusted to 6 minutes every hour.

Research Results. The growth and development of lettuce in water pipes in open fields were monitored through phenological observations and biometric measurements. During these observations, seedling survival rate,

head formation, technical maturity, harvest time, the number of surviving plants per hectare, and the overall growing period were determined (see Table 1).

According to the data on seedling survival rates, the results across varieties ranged from 93.0% to 97.2%. The highest survival rate was observed in the *Robinson* variety at 97.2%. The lowest survival rate was found in the control variety, *Krupnokochan*, at 93.0%. Other varieties showed survival rates between 94.3% and 95.9%. This indicates that even under identical regional conditions, different varieties exhibit varying seedling survival capacities.

Table 1

Results of phenological observations in the cultivation of lettuce varieties in water pipes in open fields (2022–2024).

Varieties	Seedling survival rate, %	Number of days from transplanting to...			Number of surviving seedlings per hectare, units	Growing period, days
		Head formation	Technical maturity of lettuce	Harvesting		
Krupnokochan (control)	93,0	24	35	38	102198	73
Iceberg	95,9	22	32	35	105384	70
Great Lakes 118	94,3	23	33	36	103626	71
Robinson	97,2	21	32	34	106813	69
Ko'kshoh	94,5	23	34	37	103846	72

The period from planting to head formation of the lettuce seedlings ranged between 21 and 24 days across the varieties. In the experiment, technical maturity was achieved within 32–35 days, with the relatively early-maturing **Robinson** and **Iceberg** varieties leading the observations. For the remaining varieties, technical maturity was recorded at 36–38 days. In our scientific study, the harvest period took place 34–38 days after transplanting, where the **Robinson** and **Iceberg** varieties again distinguished themselves as the earliest. This is undoubtedly attributed to the high germination rates, rapid development, seedling survival, and superior climate adaptation of these specific varieties.

Determining the number of surviving plants in the field is a crucial indicator for establishing the primary yield potential. According to the calculations, the number of surviving plants per hectare across the varieties was as follows: 102,198 units for the **Krupnokochan (control)** variety, 105,384 units for **Iceberg**, 103,626 units for **Great Lakes 118**, 106,813 units for **Robinson**, and 103,846 units for **Kokshokh**.

The total duration of the vegetation period in the experiment ranged from 69 to 73 days. Among them, the **Robinson** variety was identified as the earliest maturing with the shortest growth cycle, lasting 63 days after transplanting. The longest vegetation period was observed in the **Krupnokochan (control)** variety, reaching 73 days. The data obtained clearly shows a distinct variation in the progression of phenophases during the growth and development stages of the variety samples.

Biometric measurements were also conducted during the study on lettuce cultivation in water pipes in open fields (see Table 2). Indicators such as plant height, root system of a single plant, number of leaves, leaf length, and leaf width were determined. Measurements were carried out over three years on 10 plants from each variety and experimental plot. According to the results, the average plant height across varieties ranged from 24.1 cm to 28.2 cm, with the highest indicator of 28.2 cm recorded in the **Krupnokochan (control)** variety.

Table 2

Results of biometric measurements in the cultivation of lettuce varieties in water pipes in open fields.

Varieties	Years	Plant height, cm	Root weight per plant, gr	Number of leaves, units	Number of leaves, units	Leaf width, cm
Krupnokochan (control)	2022	28,2	28	23,4	24,8	10,8
	2023	37,0	32	24,9	27,0	13,2
	2024	29,4	31	24,1	26,2	12,3
	average	28,2	30,3	24,1	26,0	12,1
Iceberg	2022	25,1	33	26,4	23,8	9,5
	2023	24,4	32	25,5	22,1	8,5
	2024	26,4	34	27,3	25,2	10,2
	average	25,3	33,0	26,4	23,7	9,4
Great Lakes 118	2022	28,3	28	22,3	25,6	11,8
	2023	26,2	25	21,7	24,1	10,1
	2024	28,6	28	23,0	26,2	12,0
	average	27,7	27,0	22,3	25,3	11,3

Robinson	2022	24,1	25	22,1	22,2	8,0
	2023	23,2	20	21,2	21,0	7,5
	2024	25,0	26	22,8	23,1	8,5
	average	24,1	23,7	22,0	22,1	8,0
Kokshokh	2022	27,3	30	24,5	25,0	10,5
	2023	26,0	31	23,8	24,1	9,5
	2024	28,0	32	25,1	25,6	10,6
	average	27,1	31,0	24,5	24,9	10,2
LSD ₀₅		4,2	5,6	3,8	3,5	1,2
Sx%		3,0	4,4	2,2	3,1	4,0

The lowest indicator for plant height was recorded in the **Robinson** variety at 24.1 cm, while the remaining varieties ranged between 25.3 and 27.1 cm. It was observed that plant height, leaf number, and leaf size varied by year; some varieties showed stronger growth in 2023, while others peaked in 2024. The analysis of the obtained data is presented as average figures.

The weight of the plant roots was also determined based on the established methodology. To find the root weight per plant, 10 plant roots were removed from the water pipes and weighed using an electronic scale. According to the results, the highest indicator was observed in the **Iceberg** variety at 33.0 grams, while the lowest was in the **Robinson** variety at 23.7 grams. In the other varieties, the weight ranged from 27.0 to 31.0 grams.

When determining the number of leaves, it was observed that the **Iceberg** and **Kokshokh** varieties had relatively higher counts (26.4–24.5 units). At the same time, the highest results for leaf length and width were found in the **Krupnokochan (control)** variety, with a leaf length of 26.0 cm and a leaf width of 12.1 cm. In the remaining varieties, leaf length ranged from 22.1 to 25.3 cm, and leaf width ranged from 8.0 to 11.8 cm.

Regarding the growth and development of the above-ground and below-ground parts of the lettuce, the **Krupnokochan (control)**, **Kokshokh**, and **Iceberg** varieties were identified as the most vigorous. Although the **Robinson** variety exhibited high seedling survival rates and early maturity, it recorded lower indicators in terms of the growth and development of its vegetative mass.

The yield indicators and quality of the produce were evaluated for lettuce cultivation in water pipes in open fields (see Table 3). Based on the research results, the average ratio of total head weight, diameter, marketable heads, non-marketable leaves, and the core part (heart) was determined for each variety over the years. Additionally, the yield per hectare and its ratio compared to the standard were calculated.

Table 3

Yield indicators of lettuce varieties cultivated in water pipes in open fields.

Varieties	Years	Total weight of lettuce head, gr	Head diameter, cm	Yield weight, g			Yield, t/ha	Compared to control, %
				Marketable lettuce head	Non-marketable leaves	Core		
Krupnokochan (control)	2022	465	25,9	372	66	17	38,4	100
	2023	491	31,0	403	74	22	40,9	
	2024	487	28,6	398	73	21	40,1	
	<i>average</i>	481	28,5	390	71	20	39,8	
Iceberg	2022	524	26,8	422	82	27	44,3	110
	2023	512	24,6	395	80	22	42,2	
	2024	536	27,8	434	84	28	45,2	
	<i>average</i>	524	26,4	417	82	25	43,9	
Great Lakes 118	2022	490	28,3	392	77	22	41,1	102
	2023	479	25,7	387	72	19	39,7	
	2024	493	29,4	397	76	22	41,0	
	<i>average</i>	488	27,8	392	75	21	40,6	
Robinson	2022	514	23,0	416	78	19	44,0	110
	2023	483	20,0	391	75	18	42,0	
	2024	515	23,6	417	78	20	44,8	
	<i>average</i>	504	22,2	408	77	19	43,6	
Kokshokh	2022	393	22,5	320	56	15	33,0	87
	2023	407	23,9	335	59	17	35,1	
	2024	424	24,7	341	62	19	35,4	
	<i>average</i>	408	23,7	332	59	17	34,5	
LSD ₀₅		48,7		32,5			3,6	
Sx%		3,6		3,1			4,5	

The average weight of the lettuce heads was determined by weighing the total yield of each variety and dividing it by the number of heads. According to the results, the head weight varied across varieties, ranging from 408 to 524 grams. The highest indicators were recorded in the **Iceberg** variety at 524 g and the **Robinson** variety at 504 g. The lowest result was observed in the **Kokshokh** variety at 408 g. In the **Krupnokochan (standard)** and **Great Lakes 118** varieties, the weights were 481 g and 488 g, respectively. These differences are attributed to the specific valuable economic traits of each variety. Regarding head diameter, the highest results were found in the standard **Krupnokochan** (28.5 cm) and **Great Lakes 118** (27.8 cm), while in other varieties, this indicator ranged from 22.2 to 26.4 cm.

In this experiment, determining the share of the marketable yield is crucial, as the marketable part represents the portion of the crop that is suitable for consumption and of high quality for sale. During each harvest, the yield was separated into marketable parts, non-marketable parts, and the core, and each was weighed individually.

The results showed that the average weight of marketable lettuce heads across varieties over the years ranged from 332 to 417 grams. The highest marketable yield was observed in the **Iceberg** variety (417 g) and the **Robinson** variety (408 g), both demonstrating higher weights due to head density. The lowest result was recorded in the **Kokshokh** variety at 332 g, while the other two varieties ranged between 390 and 392 g. This indicator is essential for calculating the yield per hectare.

Loose, deformed, decayed, or yellowed leaves were weighed as non-marketable yield. Across varieties, this indicator ranged from 59 to 82 grams, with the highest non-marketable yield observed in the **Iceberg** variety at 82 grams. The share of the core part of the lettuce was also determined. Results showed that the core weight varied from 17 to 25 grams among the varieties. This is one of the factors affecting product quality, as a reduction in the core part leads to an increase in the share of the marketable yield.

The yield per hectare of the lettuce plants was also calculated. The marketable yield from each plot was weighed annually and extrapolated to a per-hectare basis. The results indicated that cultivating lettuce in water pipes in open fields consistently resulted in higher yields over the years compared to traditional soil cultivation.

The average yield indicators over three years ranged from 34.5 t/ha to 43.9 t/ha. The highest yields were recorded in the **Iceberg** (43.9 t/ha) and **Robinson** (43.6 t/ha) varieties. The lowest yield recorded was 34.5 t/ha, while other varieties yielded between 39.8 and 40.6 t/ha. Naturally, this depends on the number of surviving seedlings per hectare.

According to the classification system in the "Broadly Unified CMEA Classifier and International CMEA Classifier for the species *Lactuca sativa var. crispata*" (1980), yields are grouped relative to the control (very low: below 70%; low: 71–90%; average or equal: 91–105%; high: 106–130%; and very high: over 130%). Our studied samples showed consistency between total and marketable yield within these groups.

Experimental results showed that the **Kokshokh** variety yielded 5.3 t/ha less (34.5 t/ha, 87%) compared to the standard **Krupnokochan** variety (39.8 t/ha). The **Great Lakes 118** variety produced a yield nearly equal to the standard (40.6 t/ha, 102%). The highest yield indicators were found in the **Iceberg** variety, which produced 4.1 t/ha more than the standard (43.9 t/ha, 110%), and the **Robinson** variety, which produced 3.8 t/ha more (43.6 t/ha, 110%) in terms of marketable yield.

The biochemical composition is one of the primary valuable economic traits of each variety. Analysis showed that the dry matter content in the lettuce varieties ranged from 5.30% to 5.75%. The standard variety had the highest dry matter content, with all other varieties recording lower levels. The lowest indicator was observed in the **Great Lakes 118** variety at 5.30% (see Table 4).

Table 4

Biochemical composition and organoleptic (sensory) evaluation of lettuce varieties cultivated in water pipes in open fields.

Varieties	Dry matter, %	Total sugar, %	Ascorbic acid, mg/100g	Nitrate content, mg/100g	Degustation score
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Krupnokochan (control)	5,75	1,5	24,3	300,5	8,5
Iceberg	5,40	1,8	25,1	281,4	9,5
Great Lakes 118	5,30	1,6	23,2	278,8	9,0
Robinson	5,50	1,5	22,8	294,3	9,5
Kokshokh	5,55	1,4	22,4	261,7	9,0

Today's market demands sweet and flavorful produce; thus, a higher sugar content significantly enhances the quality of lettuce heads. In the studied varieties, the sugar content ranged from 1.4% to 1.8%, with the highest indicator recorded in the **Iceberg** variety (1.8%) and the lowest in the **Kokshokh** variety (1.4%). Other varieties ranged between 1.5% and 1.6%. Ascorbic acid content is another vital characteristic, with experimental values ranging from 22.4 to 25.1 mg/100g. The **Iceberg** variety achieved the peak value of 25.1 mg/100g, followed by the standard **Krupnokochan** at 24.3 mg/100g.

In Uzbekistan, the maximum permissible limit for nitrate content in lettuce is 800 mg/kg. Nitrates serve as a primary indicator of food safety and quality. In this experiment, nitrate levels in the lettuce heads ranged from 261.7 to 300.5 mg/kg, proving they remain well within safety standards and are fit for consumption. The highest accumulation was observed in the standard **Krupnokochan** (300.5 mg/kg), while other varieties ranged from 261.7 to 294.3 mg/kg.

Sensory evaluation is another essential economic trait. The taste, color, appearance, leaf density, and overall quality of lettuce grown in water pipes were assessed on a 10-point scale. Minor variations were observed, with the **Iceberg** and **Robinson** varieties receiving the highest scores of 9.5. The standard **Krupnokochan** received the lowest score of 8.5, while **Great Lakes 118** and **Kokshokh** were rated at 9.0. This confirms that the **Iceberg** and **Robinson** varieties possess superior organoleptic qualities when cultivated hydroponically in open fields.

Overall, the **Iceberg** variety stood out for its high sugar and ascorbic acid content, superior sensory scores, and low nitrate levels, establishing it as a high-quality product.

Conclusion

1. When cultivating lettuce varieties in water pipes in open fields, the growing season duration ranged from 69 to 73 days. The **Robinson** variety was identified as the earliest maturing with a 63-day cycle, while the standard **Krupnokochan** was the latest at 73 days.
2. Regarding the growth and development of above-ground and below-ground parts, the **Krupnokochan (standard)**, **Kokshokh**, and **Iceberg** varieties showed the most vigorous growth. Although the **Robinson** variety had high seedling survival and early maturity, it recorded lower indicators for vegetative development.
3. Average yield indicators over three years ranged from 34.5 t/ha to 43.9 t/ha. The highest yields were achieved by **Iceberg** (43.9 t/ha) and **Robinson** (43.6 t/ha), while the lowest was 34.5 t/ha. Other varieties produced between 39.8 and 40.6 t/ha.
4. Compared to the standard **Krupnokochan** (39.8 t/ha), the **Kokshokh** variety yielded 5.3 t/ha less (34.5 t/ha, 87%). The **Great Lakes 118** variety was nearly equal to the standard (40.6 t/ha, 102%). The **Iceberg** and **Robinson** varieties outperformed the standard by 4.1 t/ha (110%) and 3.8 t/ha (110%) respectively, in terms of marketable yield.
5. Among the varieties cultivated hydroponically in water pipes, the **Iceberg** variety was recognized for its exceptional quality, characterized by high sugar and ascorbic acid content, excellent sensory ratings, and safe nitrate levels.

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